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OF THE

Elisha Mitchell Scientific Society

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PROCEEDINGS OF THE TWENTY-NINTH ANNUAL MEETING OF THE NORTH CAROLINA ACADEMY OF SCIENCE

DUKE UNIVERSITY, DURHAM, N. C., MAY 9 AND 10, 1930

The twenty-ninth annual meeting of the North Carolina Academy of Science was held at Duke University, May 9 and 10, 1930. The meeting was called to order at 10:00 A.M. on May 9 by President Derieux. The reading of papers was begun and continued until 12:50 P.M. when the Academy adjourned for lunch, after the appointment of the following committees by the president:

Auditing—G. S. Avery, F. W. Sherwood, W. T. Wright.

Nominating—Collier Cobb, J. P. Givler, A. S. Wheeler.

Resolutions—George W. Lay, W. L. Porter, I. V. Shunk.

The reading of papers was resumed at 2:30 P.M. and continued until 4:45, when the Academy went into business session.

The minutes of the previous meeting were approved as published in the *Journal of the Elisha Mitchell Scientific Society.*

Reports were called for from the various committees.

The executive committee, consisting of J. B. Derieux, president of the Academy, J. B. Bullitt, vice-president, H. R. Totten, secretary and treasurer, W. C. George, F. A. Wolf, and Bert Cunningham, reported as follows:

"The executive committee met at Durham, May 8 and again on May 9, with all members present.

"The committee passed favorably on the request of the secretary that the demonstration of Professor Charles W. Edwards, 'Optical

Properties of Electrical Waves,' be placed first on the Saturday morning program; and that the title of a paper received from Dr. J. M. Bell too late for publication, 'Dr. F. P. Venable's Contributions to Chemistry,' be added to the program and be placed as the last paper for Friday afternoon.

"The committee reports as elected to membership since the last annual meeting the following:

Anderson, W. A., Professor of Sociology, State College.
Bigelow, Lucius A., Assistant Professor of Chemistry, Duke University.
Black, C. S., Professor of Chemistry, Wake Forest College.
Bookhout, Cazlyn G., Instructor in Biology, North Carolina College.
Boyd, Harriett M., Instructor in Biology, Meredith College.
Braun, M. L., Instructor in Physics, University of North Carolina.
Buell, Jesse H., Assistant Silviculturist, Appalachian Forest Experiment Station, Asheville, N. C.
Cable, Louella E., Junior Aquatic Biologist, U. S. Biol. Station, Beaufort, N. C.
Callahan, Dixon, Graduate Student in Physics, Duke University.
Carroll, Zoe Wells, Research Assistant in Zoology, Duke University.
Chesley, L. C., Graduate Fellow in Zoology, Duke University.
Eliason, Nancy B., Graduate Student in Botany, University of North Carolina.
Fussler, Karl H., Professor of Physics, University of North Carolina.
Glass, Miss Jewel Jennette, Graduate Student in Geology, University of North Carolina.
Goodwin, H. S., Student in Chemistry, Davidson College.
Grimsley, Miss Gertrude, Graduate Student in Botany, North Carolina College.
Gutsell, J. S., Biologist, U. S. Bureau Fisheries, Beaufort, N. C.
Hickson, A. O., Assistant Professor of Mathematics, Duke University.
Hoyle, H. B., Science Teacher, Chapel Hill High School.
Juredine, Gordon M., Professor of Chemistry, Mars Hill College.
Mann, Frankie Jo, Student in Biology, North Carolina College.
W. M. Mebane, Professor of Chemistry, College of Asheville, Asheville, N. C.
Memminger, C. G., Mining Engineer, Asheville, N. C.
Miles, E. R. C., Assistant Professor of Mathematics, Duke University.
Pace, D. M., Graduate Fellow in Zoology, Duke University.
Saylor, John H., Instructor in Chemistry, Duke University.
Schallert, Miss Dorothy, Teaching Assistant in Zoology, Duke University.
Schomer, Harold A., Instructor in Botany, Duke University.
Stephens, H. W., Fellow in Physics, Duke University.
Tipton, S. R., Graduate Assistant in Zoology, Duke University.
Vosburgh, Warren C., Assistant Professor of Chemistry, Duke University.
Warfield, C. N., Professor of Physics, North Carolina College.
Williams, Harold F., Assistant in Botany, Duke University.

Winston, S. R., Assistant Professor of Sociology, State College.
Yarbrough, Mary E., Instructor in Chemistry, Meredith College.

Reinstated to membership:
Barrett, Dr. H. P., Charlotte, N. C.
Marion, Professor S. J., Lenoir-Rhyne College, Hickory, N. C.
Wentz, B. A., Catawba College, Salisbury, N. C.
Winsor, A. S., University of North Carolina.

Lost by death:
Roller, A. F., Professor of Science, East Tennessee State Teachers College, Johnson City, Tenn. Died January 19, 1930.

Lost by resignation:
Bender, J. A.
Braxton, H. H.
Eliason, Mary H.
Gray, Cora E.
Lindsey, John B.
Meserve, C. F.
Smiley, T. B.
Wilkins, W. E.

The executive committee made the following recommendations to the Academy.

1. "That all bills presented in the Treasurer's report be authorized and paid and that the report be printed when audited.

2. "That H. B. Arbuckle be appointed a committee of one to select the cup to be given to the winner of the high school science essay prize, and that he be authorized to draw upon the treasury for as much as $25 for the cup; that the Academy send a representative to the commencement of the Monroe High School to deliver this Academy prize; and that the Secretary be authorized to select the Academy representative and to pay the expenses of his trip from the Academy funds.

3. "That the Academy accept the invitation from State College to hold the thirtieth annual meeting of the Academy in Raleigh.

4. "That Dr. F. P. Venable be made an honorary life member of the Academy."

The recommendation of the executive committee were adopted, and their report accepted.

The committee on high school science, consisting of R. N. Wilson, chairman, C. M. Heck, H. B. Arbuckle, Bert Cunningham, and Miss Lena Bullard, submitted the following: "Your committee reports

1. "That we held one meeting.

2. "That we have conducted a science essay contest among the high school students of the state. The fields chosen for this year were physics and chemistry. Science teachers were asked to submit not more than three papers from any school. On this basis thirty papers were received, representing fourteen schools. Five of the essays were on subjects in physics and the remainder on chemistry topics.

A committee of three members of the Academy judged the papers and the award was made to Calhoun Pruitt of the Monroe High School on his paper 'The Value of Chemistry in Medicine.' We recommend that the usual prize be given as heretofore.

"The committee believes that this contest can be improved by a more energetic campaign on the part of the committee, and by some changes in the regulations under which it is conducted.

3. "The committee has in some way lost a member. The original quota was six. We have no record at present of more than five. We suggest that the President of the Academy be asked to increase the number of the new committee to six.

4. "The committee looks with some apprehension on the tendency in some of the schools to diminish the amount of laboratory work required in science courses. We believe that laboratory work is essential to any course in school science.

5. "We recommend that the incoming committee be requested to hold a meeting at an early date, before June 1st if possible, to outline plans for the participation of Academy members in the district meetings of the North Carolina Education Association which are held in October and November. We believe that these sectional meetings of science teachers are important and that the presence of a representative from the academy at each of them would not only be welcomed by the teachers, but would be most helpful."

The report of the committee was accepted.

The resolutions committee reported as follows:

"In the first place, we wish to extent to Prof. G. D. Collins of the physics department of Duke University our sincere sympathy in his recent great loss in the death of his wife.

"Secondly, whereas since our last meeting our beloved member, A. Fleetwood Roller, has been called to the Great Beyond, be it resolved:

"That in his death the North Carolina Academy of Science has lost a faithful and enthusiastic member and one who strove for the upbuilding of science in the high schools of North Carolina. We wish to gratefully acknowledge Prof. Roller's work on the high school science com-

mittee of the Academy in which he was active for some years. Mr. Roller's death resulted from septemic poisoning caused by infection from the bite of a rat used in his experimental work. As a group of scientists, we wish to recall the fact that he lost his life in pursuing scientific investigations.

"Lastly, the North Carolina Academy of Science desires to express its cordial appreciation of the generous and kindly hospitality extended to it by the authorities of Duke University and the individual members who have contributed to the success of this meeting and to the enjoyment of those in attendance. Also the Academy extends to Duke University its hearty congratulations on the visible evidence of its physical growth and its sincere hope and belief that it will continue through the years to increase in power and usefulness and in those invisible ways that are of greatest importance."

Submitted by the committee,
W. L. PORTER
GEORGE W. LAY
I. V. SHUNK

The report of the committee was adopted by rising vote.

The committee on zoological nomenclature, consisting of Z. P. Metcalf, chairman, Bert Cunningham, and C. S. Brimley, submitted the following report on the proposed amendments to the International Rules of Zoological Nomenclature.

"The committee recommends proposition 1930A, but would favor 1930B if the majority was 2/3 instead of 5/6.

"The committee recommends that 1930D be reported unfavorably.

"The committee recommends proposition 1930E as favorable.

"The committee recommends that 1930F be reported unfavorably.

"The committee recommends that 1930G be reported unfavorably.

"The committee recommends proposition 1930H, with the recommendation that Italian and Spanish be stricken from the list of languages to be used in summaries.

"The committee recommends proposition 1930I as favorable.

"The committee recommends proposition 1930J as favorable."

The auditing committee reported that they had gone over the Treasurer's accounts from May 9, 1929, to May 6, 1930, and found them correct.

The Treasurer's report was as follows:

Financial Statement

Receipts		Expenditures	
Balance on hand, May 8, 1929	$745.04	Stationery, postage	$107.35
Dues, for		Printing, mimeo. and multigraphing and addressographing	52.75
1929	85.90	Journal of the E.M.S.S.	300.00
1930	300.00	Clerical assistance	72.00
1931	4.00	Office supplies	3.40
Initiation fees at 1929 Meeting	22.00	High School Science Prize	21.00
Since 1929 Meeting	48.00	Expenses of Academy representative to deliver High School Prize	13.85
Interest on Savings	19.37	Sec'y-Treas. commission	45.80
Sale of Membership list	1.00	Dues refund to Sec'y-Treas.	2.00
	$1225.31	Expenses of the Sec'y-Treas. at the Greensboro Meeting	4.08
		Protested check	2.00
			$624.23
		To balance	$601.08
			$1225.31

Comparison

	1929	1930
Savings account	477.52	496.89
Checking account	252.52	92.19
Cash on hand	15.00	12.00
	$745.04	$601.08
To balance		143.96
		$745.04

The above report was made as of May 6, 1930.

Submitted by

H. R. Totten, *Secretary-Treasurer.*

Audited by

W. T. Wright, *chairman.*

F. W. Sherwood

Date May 9, 1930.

The Treasurer's report was accepted.

The nominating committee submitted the following nominations:

President—W. F. Prouty, University of North Carolina.

Vice-president—P. M. Ginnings, Greensboro College for Women.

Secretary-Treasurer—H. R. Totten, University of North Carolina.

New member of the executive committee for three years—W. L. Porter, Davidson College.

A vote was taken and the above officers elected.

E. E. Randolph moved that the Academy commend and express its appreciation to Dr. F. P. Venable for his many services to the Academy, to science, and to the state. This motion was carried unanimously by a rising vote.

Dr. Otto Stuhlman brought up the question as to the ruling of the executive committee that papers presented before the Academy be confined to members of the Academy. Several members of the executive committee defended the position of the committee. No formal action was taken by the Academy.

The following committees for the coming year were appointed.

Committee on high school science: Bert Cunningham, chairman, H. B. Arbuckle, Lena Bullard, Carleton E. Preston, C. M. Heck, and R. N. Wilson.

Legislative: Z. P. Metcalf, chairman, W. L. Poteat, and C. S. Brimley.

The business meeting then adjourned for a picnic supper and tour of the new Duke campus.

The Academy reconvened at 8:30 P.M. with Vice-president J. B. Bullitt presiding. W. H. Wannamaker, Dean of Duke University, gave the address of welcome. President J. B. Derieux responded for the Academy and delivered the presidential address on "The Corpuscular Theory of Radiation and the Wave Theory of Matter" [see p. 27].

After this a reception was given the Academy by Duke University.

The Academy convened in sections on Saturday A.M. with President Derieux presiding over the general section; Helen Barton over the mathematicians; Otto Stuhlman over the physicists; and Frank K. Cameron over the chemists.

The following group officers were elected by the group concerned for the year 1930–31:

Chemistry—L. A. Bigelow of Duke University, chairman; A. J. Wilson of State College, vice-chairman; H. D. Crockford of the University of North Carolina, secretary-treasurer; L. G. Willis of State College, councillor.

Mathematics—W. W. Elliott of Duke University, chairman; E. L. Mackie of the University of North Carolina, secretary.

Physics—A. A. Dixon of State College, chairman; W. E. Speas of Wake Forest, secretary.

The following papers were presented. Those marked with an * appear in full in this issue; those marked x are abstracted in this issue; for those unmarked no abstract was received; those marked † were presented by title only.

GENERAL SECTION

x *Further Studies on Sterility.* BERT CUNNINGHAM and DOROTHY SCHALLERT, Duke.

x *A Study of the Purification of Waste Gas Liquor.* E. E. RANDOLPH, State.

An Interesting Moss from North Carolina. H. L. BLOMQUIST, Duke.

The So-called "Oil Domes" of the North Carolina Coastal Plane. COLLIER COBB, U. N. C.

x *Native Storage of Ice, Shanghai* (Lantern). MILTON L. BRAUN, U. N. C.

x *The Distribution of Vitamin B. and Its Components in the Peanut* (Lantern). F. W. SHERWOOD and J. O. HALVERSON, State.

* *Additions to the List of North Carolina Birds.* C. S. BRIMLEY, Dept. of Agr.

Durham Basin Triassic and Its Structural Relationships (Lantern). W. F. PROUTY, U. N. C.

x *Some Prehistoric Scraps* (Lantern). J. B. BULLITT, U. N. C.

Sub-alpine Plant Communities in the Mountains of Western North Carolina (Lantern). JOHN H. DAVIS, Jr., DAVIDSON.

* *The Bald Cypress.* W. C. COKER, U. N. C.

x *The Language of Scientists.* REV. GEO. W. LAY, Chapel Hill.

x *Science in Preparation for High School Teaching.* CARLETON E. PRESTON, U. N. C.

Wintering Honeybees in North Carolina (Lantern). F. B. MEACHAM, State.

* *The Effect of Nitrate Fertilizer on Stomatal Movement* (Opaque Projector). ANNIE L. PLEASANTS, N. C. C.

x *Preliminary Report on Winter Root Development of Shrubs.* L. EDWIN YOCUM, N. C. C.

* *Winter Root Development of Ligustrum vulgare* (Lantern). FRANKIE JO MANN, N. C. C.

Dr. F. P. Venable's Contributions to Chemistry. J. M. BELL, U. N. C. Published in Journ. Chem. Educ. **7**: 1300. 1930.

† *Further Studies in the Relation between Septobasidium and Scale Insects.* J. N. COUCH, U. N. C.

The Ability of Marine Fishes to Remove Dissolved Oxygen (Lantern). F. G. HALL, Duke.

The Amylase Activity in Marine Fishes (Lantern). L. C. CHESLEY, Duke.

x *The Influence of Insulin on Glycogen Distribution in Fishes* (Lantern). RAYMOND W. ROOT, F. G. HALL, and I. E. GRAY, Duke.

x *The Toxicity of Cotton Seed Meal* (Lantern). J. O. HALVERSON and F. H. SMITH, State.

x *Optical Properties of Electrical Waves* (Demonstration). CHARLES W. EDWARDS, Duke.

Electrical Resistivity: A New Stratigraphic Aid. J. H. SWARTZ, U. N. C.

Structure and Chemical Composition of Mature Tobacco Leaves, from Bottom to Top of Stalk (Lantern). G. S. AVERY, JR., F. R. DARKIS, and J. A. HALL, Duke.

x *A Correlation between Seedling Anatomy and Geographical Distribution of Certain Grasses.* H. F. WILLIAMS, Duke.

* *A Partial Check List of Ferns Found in the Mountain Park and Roaring Gap Region.* EARL H. HALL, N. C. C.

x *Vegetation of the Artificial Lakes of Western North Carolina* (Lantern). S. O. TRENTHAM, Duke.

* *Duplicity and Other Abnormalities in Diamond-back Terrapins* (Lantern). S. F. HILDEBRAND, Beaufort Biol. Sta.

x *The Embryology of the Seventeen-year Cicada (Magicada septemdecim)* (Lantern). Z. P. METCALF, State.

* *The Jonesboro Fault West of Cary* (Lantern). E. F. GOLDSTON AND JASPER L. STUCKEY, State.

x *A Mechanical Analysis of Atlantic Beach Sands.* G. R. MACCARTHY, U. N. C.

Larkspur Blight. F. A. WOLF, Duke.

Studies on the Genus Pythium. VELMA DARE MATTHEWS, U. N. C.

Seed Development in Cotton and Okra. REBECCA WARD, U. N. C.

Observations on the Flowers and Seed of Morning Glory. NANCY ELIASON, U. N. C.

x *Serpentine Marble Deposits of the Maryland-Pennsylvania Area* (Lantern). W. F. PROUTY, U. N. C.

x *The Moss Flora of Durham and Vicinity.* H. L. BLOMQUIST, Duke.

* *The Rediscovery of Lycogalopsis Solmsii Ed Fischer in Honduras.* W. C. COKER, U. N. C.

* *Some Observations on Tilia (Basswood) Seeds* (Lantern). GERTRUDE GRIMSLEY, N. C. C.

MATHEMATICS SECTION

x *Some Properties of Transon's Auxiliary Conic.* J. W. LASLEY, Jr., U. N. C.

x *The Euler Condition for a Problem in the Calculus of Variations.* ERNEST L. MACKIE, U. N. C.

x *The Stieltjes Integral in the Theory of Probability.* E. R. MILES and F. G. DRESSEL, Duke.

x *On the Expression of an Integer as the Sum of an Arithmetic Series.* L. E. BUSH, U. N. C.

The Equations of Motion of the Vertices of a Triangle under Given Conditions. A. S. WINSOR, U. N. C.

x *The Characteristic Roots of a Matrix.* EDWARD T. BROWNE, U. N. C.

PHYSICS SECTION

x *The Relation Between Molecular Structures and Absorption Spectra.* E. K. PLYLER, U. N. C.

x *The Relation Between the Intensity and Position of the Overtones of Some Organic Liquids.* P. E. SHEARIN and E. K. PLYLER, U. N. C.

x *The Absorption of Light by Certain Fluorescent Dyes.* H. W. STEPHENS, Duke.

Some Notes on the Raman Effect in Inorganic Substances. DIXON CALLIHAN, Duke.

x *The Determination of Current, Frequency and Pressure Relationships for Initiating and Maintaining the Electrodeless Glow Discharge.* MILTON L. BRAUN, U. N. C.

x *The Photometric Characteristics of the Electrodeless Discharge in Air and Mercury Vapor.* M. D. WHITAKER, U. N. C.

x *Relative Intensities of Arc and Spark Lines of the Electrodeless Discharge in Mercury Vapor.* O. P. HART, U. N. C.

x *The Effect of External Resistance in the Plate-Filament Circuit of Radiotrons.* K. Z. MORGAN, U. N. C.

x *A Note Concerning the Diffusion of Gases.* CHARLES W. EDWARDS, Duke.

The Motion and Bursting of Gas Bubbles (Lantern). OTTO STUHLMAN, Jr., U. N. C.

EXHIBITS

Prehistoric Implements. J. B. BULLITT, U. N. C.

The Moss Flora of Durham and Vicinity. H. L. BLOMQUIST, Duke.

Articulated Skeletons of Very Small Vertebrates Prepared by a Simple Technique. W. C. GEORGE, U. N. C.

Maturation Mitoses in the Ova of a Guinea Pig. W. C. GEORGE, U. N. C.

Apparatus for Incubating Hen's Eggs under Pressure. BERT CUNNINGHAM, Duke.

NORTH CAROLINA SECTION OF THE AMERICAN CHEMICAL SOCIETY

The Solubility of Some Organic Substances in Water. J. H. SAYLOR and PAUL GROSS, Duke.

Deaeration vs. Deactivation in Boiler Waters. F. C. VILBRANDT and W. A. PERRY, U. N. C.

Ternary Systems: Water Tertiary Butanol and Salts at 30 Degrees. P. M. GINNINGS and DOROTHY ROBBINS, G. C.

Bromination of 1, 5—Dihydroxynaphthalene. A. S. WHEELER and D. R. ERGLE, U. N. C.

Chlorination of 1, 5—Dihydroxynaphthalene. A. S. WHEELR and W. J. MATTOX, U. N. C.

Some Observations on the Structure of P-Dimethylaminobenzoin. L. BIGELOW and S. S. JENKINS, Duke.

Chemical Constitution of Shrimp Oil. F. C. VILBRANDT and R. F. ABERNETHY, U. N. C.

Stabilities of Some Chlora-Imines. C. R. HAUSER, Duke.

Differential Fractional Distillation. P. M. GINNINGS, G. C.

Iodine Compounds in Penaea setifera. F. C. VILBRANDT and H. PARKER, Jr., U. N. C.

The Preparation of Nitrites of Chlori-Imines. C. R. HAUSER and A. GILLASPIE, Duke.

Pressure Factors in Cotton Mercerization. F. C. VILBRANDT and E. E. HOFFMAN, U. N. C.

Effect of Certain Growth Factors on Chemical Composition of Cotton Seed. F. C. VILBRANDT and J. R. MURPHY, U. N. C.

Some Limitations in the Use of Ammonia in Concentrated Fertilizers (Lantern). L. G. WILLIS and J. R. PILAND, State.

Economic Consideration in the Cotton and Cotton Seed Industry. F. C. VILBRANDT and J. H. SANDERS, U. N. C.

The Preparation and Properties of Certain Thiophanes. R. W. BOST and M. W. CONN, U. N. C.

x *The Absorption of Sulphur Dioxide by Tricalcium Phosphate and Phosphate Rock.* FRANK K. CAMERON and A. E. HUGHES, U. N. C.

† 4-*p*-*Tolylthiosemicarbazide as a Ketone Reagent.* R. W. BOST and W. F. SMITH, U. N. C.

† *Aqueous Solutions of Copper Sulphate.* H. D. CROCKFORD and MAUDE M. WEBSTER, U. N. C.

Cyclohexylcarbithioic Acid and Its Derivatives. R. W. BOST and W. W. WILLIAMS, U. N. C.

The following abstracts have been received:

Further Studies on Sterility. BERT CUNNINGHAM and DOROTHY SCHALLERT.

The report is divided into three parts. The first reports the continuation of studies with infra-red sterility, which confirms earlier work. The second reports a new study in which environmental temperatures were able to induce sterility, and the third reports a selective sterility, more common in the male, produced by thyroid feeding.

A Study of the Purification of Waste Gas Liquor. E. E. RANDOLPH.

In a rapidly growing industrial center stream pollution becomes a serious problem. The effluent waters from the various industries require individual study and treatment to render them unobjectionable or suitable for further use.

The waste liquors from city gas plants form an especially interesting problem for the chemical engineer because his mind is seriously disturbed by the idea of loss of valuable by-products and by the complications which the discharge of this type of waste product involves.

In cities in which the gas consumption is large enough to justify the by-products coke over the by-products are recovered and consequently stream pollution is eliminated. In the small city, however, the expense of recovery of all of the by-products is too great to justify the great expense of a by-product installation.

The problem is to purify the gas liquor sufficiently for recirculation throughout the gas plant system or for discharge into the stream below in such a condition that it would not cause objection.

The principal objections to the unpurified gas liquor in the streams are that it gives a tarry odor, it leaves a black deposit along the banks of the stream, it affects the fish in the stream, gives a medicinal taste to

the drinking supplies after chlorination, and it affects the bacteria which decompose sewage in case the liquor is emptied into the city sewerage system.

The principal constituents which cause objections are: Tar, oil, hydrogen sulphide, ammonia, naphthalene, and phenols.

The ammonia and hydrogen sulphide could be removed by a spray tower, but the hydrogen sulphide would affect the paint of the buildings in the neighborhood and would give a disagreeable odor.

The plan proposed is to collect the strong ammonia liquor from the scrubber and tar well and from the water gas machine and the coke quenching water into a treating basin. For plant producing half-million cubic feet of gas per day the discharge water is about thirty thousand gallons. In order to give a five-hour travel for this liquor a basin is divided into three compartments five feet wide and nine feet deep and 38 feet long. In the first compartment a baffle separator removes the tar and oil. The second and third compartments are used for treating basins. The proper amount of iron sulphate is added in solution and mixed by baffles. The sulphur is removed as iron sulphide. This sludge is pumped out on the yard to aerate for use as a purifying material in the gas purifiers. The third compartment of the basin is used as a treating chamber when the sludge of the second compartment is being pumped out. The liquor is then run through a lime treating compartment and then through a twin compartment coke filter. Any residual sludge, breeze, tar and oil, and some of the naphthalene and phenol products are removed. The water is then pumped to a spray tower where the remaining ammonia and other volatile substances are removed. The filter coke is burned under the boilers of the plant.

This treatment has been found to yield a water suitable for discharge into the streams and suitable for recirculation through the plant except the boilers.

The advantages of this system are that the operating expense is small. It is practically automatic and yields an unobjectionable effluent. Also, the tar and oil are recovered, and the iron sulphide when oxidized on the yard, is suitable for a purifying material to remove the sulphur from the gas.

[Summary of an investigation for the Carolina Power and Light Company, given with their permission.]

The Native Storage of Ice, Shanghai. MILTON L. BRAUN.

Only recently, years after the migration to China of the American appetite for cold beverages and frozen dishes, has there appeared an

acquired taste on the part of natives of the metropolitan area of Shanghai for chilled food—a departure from the taste of their fathers as radical as the western style of dress adopted by a portion of young China is from the type of garments it displaces. This perversion of the appetite is creating a new demand for ice—one of nature's products hitherto ignored in the economy of the nation. A series of pictures shows how one enterprising farmer on his acre of ground in the suburbs of Shanghai obtained, in addition to his usual crop of rice and seasonal catch of fish, a thousand ton harvest of ice, which he transfers in broken pieces by basket to a copiously spaced thatched and straw insulated storage house erected entirely above ground and exposed to the unshaded bombardment of a summer sun of latitude equivalent to that of Jacksonville, Florida. The venture is a success.

The Distribution of Vitamin B and Its Components in the Peanut. F. W. SHERWOOD and J. O. HALVERSON.

Choice whole raw Virginia runner peanuts were separated into splits (cotyledons), hearts (plumules and hypocotyls) and red skins (seed coats). Rat feeding tests show that raw red skins contain the highest concentration of vitamin B complex. There was appreciably less vitamin B complex in commercially blanched splits and the by-products, hearts and red skins, than in the corresponding raw products. Whole raw peanuts are fairly rich in the antineuritic vitamin B. They contain relatively less vitamin G. A commercial peanut meal contained somewhat less antineuritic vitamin and slightly more vitamin G. than whole raw peanuts.

Some Prehistoric Scraps. J. B. BULLITT.

This paper deals sketchily with the development and peculiarities of paleolithic art. The illustrative lantern slides were partly from photographs and partly from pencil sketches made in the caves and rock shelters in southern France and northern Spain.

The Language of Scientists. GEORGE W. LAY.

In addition to a knowledge of his own specialty, every scientist should be interested in speaking and writing English correctly. They are apt to fall into common errors in pronunciation, and in the use of words and phrases from foreign languages due to ignorance of their original meaning. "Micromicron" and "Pedology" are examples of confusion. There is need of a central authority on terminology and of accuracy and

simplicity in nomenclature. There is difficulty for the scientist in using words from Latin and Greek, and he should know something of these languages. Scientific books should more generally give the derivation and pronunciation of all unfamiliar words.

Science in Preparation for High School Teaching. CARLETON E. PRESTON.

Advancement of science depends not only on research but on interpretation of research to the public. College faculties, largely composed of those who hold degrees and positions by virtue of their researches and naturally maintain their research interest, have not realized adequately the difference in the training needed by interpreters, such as high school science teachers, and that needed by research workers. The latter need detail in a limited field; the former, breadth to see science as a whole in all its interrelations and applications, unobscured by too much detail. There is scarcely any opportunity in colleges today for prospective high school science teachers to get the type of content instruction that they need for their work. In too great degree present college courses are highly departmentalized rather than comprehensive, framed rather toward taking more of the same science than toward giving an insight into the part played by science in everyday life. In particular there is need for general science courses, biological and non-biological, at a level higher than that of the secondary school, stressing those aspects of science most directly concerned with the environmental adjustment of the average citizen.

Preliminary Report of Studies on Winter Root Development of Shrubs. L. EDWIN YOCUM.

Abelia grandiflora, Ligustrum lucidum, and *Spirea Thunbergii* were transplanted at several periods from October 8 to April 1, in order to find the relation of transplanting time to root development. All these roots have a rest period during the winter. When transplanted in fall or winter these shrubs developed many more roots, and began root development earlier than when not transplanted. Transplanting produced the greatest stimulus on *Spirea,* next on *Abelia,* and least on *Ligustrum* with respect to root development.

The Influence of Insulin on Glycogen Distribution in Marine Fishes. R. W. ROOT, F. G. HALL, and I. E. GRAY.

The distribution of glycogen in the liver and skeletal muscle, and the

blood sugar level were studied in the Scup, *Stenotomus chrysops* (Linnaeus), both under normal conditions and when insulin was administered. Massive injections of insulin (40 units per kilo body weight) are followed first by a transient hyperglycemia and then a gradual hypoglycemia down to a very low level. The glycogen concentration in the liver falls below normal. Concomitant with this drop in liver glycogen there is a gradual rise in muscle glycogen above normal, the peak occurring about six hours after the injection of insulin. It would appear that injections of insulin are followed by a change in the distribution of carbohydrates wherein more are stored in the muscles and less in the liver, relative to the amounts normally occurring in these structures.

The Toxicity of Cotton Seed Meal. J. O. HALVERSON and F. H. SMITH.

The results of work at this station have shown that the symptoms of cottonseed meal poisoning can be simulated by feeding other meals to cattle, and that this conditions can be alleviated by supplying to the ration the proper nutritive adjuvants.

The results to date of last year's meals (1928) and of the local meal of last fall (1929) show that only a minute amount of gossypol is present. Special precautions and procedure are necessary in order to estimate these small amounts of gossypol. From the data and knowledge at hand we can state that these meals are not toxic.

It should also be mentioned that the quality of seed in the years 1928 and 1929 was poor and variable. Much seed was fermented and spoiled. Meals made from this seed varied considerably. There is some suggestion that the amount of gossypol also varies. We do know the content of gossypol in the meals during the years when the seed was of uniform quality.

Optical Properties of Electrical Waves. CHARLES W. EDWARDS.

The brilliant work of Heinrich Hertz in 1888 in verifying the prediction of Maxwell concerning the existence of electric waves was repeated by making use of a powerful vacuum tube oscillator as a source of waves. Flash light bulbs were lighted in the resonating circuit where Hertz observed minute sparks. Polarization, plane reflection, stationary waves along wires and in air were produced and wave lengths were measured both directly and by means of wave meters. The composition of two waves oscillating in planes at right angles was demonstrated. The apparatus employed was designed and manufactured in America.

A Correlation between Seedling Morphology and Geographical Distribution of Certain Grasses. H. F. WILLIAMS.

There seems to be a correlation between systematic and geographical distribution of the grasses with reference to the three types of seedling morphology which at once fits into the present taxonomic scheme and which, as more data are gathered, may possibly aid in the development of a more sound conception of the systematic relations of the group.

Vegetation of the Artificial Lakes of Western North Carolina. S. O. TRENTHAM.

A preliminary report of a study of the vegetation of the artificial lakes of Western North Carolina, comprising seventeen counties. There are about seventy-five artificial lakes in this section ranging in size from 1 to 1500 acres, in age from 2 to 36 years, and located at an average altitude of 2700 feet. The purpose of this study was to determine the comparative effects of these lakes upon the vegetation in relation to certain environmental conditions. In general the effects of these lakes are unfavorable and favorable: unfavorable due to denudation, flooding, and drying of stream beds below dams; favorable for certain types of plants, especially hydrophytes and marsh plants, due to increase in area of water habitat. The flora of these lakes differ considerably due to kinds and amount of plants introduced and to the extent of sedimentation which in turn are related to environmental conditions. The actual age of the lakes can, therefore, not be determined by the apparent age indicated by vegetation present. Initial stages in plant establishment and early successions were studied and in some cases all stages from submerged communities to a woodland forest were observed. A list of approximately 260 species representative of the flora of these lakes is included.

The Embryology of the Seventeen-year Cicada (Magicada septemdecim). Z. P. METCALF.

This paper discusses the embryology of the seventeen-year locust, especially the development of the regions of the head of the Cicada, and reaches the conclusion that the face of the Cicada is composed of the clypeus, anticlypeus and labium. The development of the mandible and maxilla in relation to the regions of the head is also discussed.

A Mechanical Analysis of Atlantic Beach Sands. G. R. MACCARTHY.

As part of a comprehensive investigation of the beach sands of the United States some interesting facts were brought out by a mechanical

analysis of about 200 samples of such sands collected along the Atlantic coast from the northern end of Long Island to Cape Lookout.

Beginning with any major interruption of the coast line, i.e., New York Harbor, Delaware Bay, Chesapeake Bay, etc., it was found that the sands grew progressively finer toward the south, this change in grain size being almost a linear function of the distance south of such an opening. This is interpreted as an effect of the mechanical wear to which the sand grains are subjected as they are carried southward by the shore currents along the coast.

Superimposed upon the effect mentioned above, another regular change in grain size was noted. This consisted of an increase in the average size of the sand grains in the immediate vicinity of each of the major openings in the coast line. This is interpreted as a result of tidal currents which, sweeping in and out of the bays four times each day, carry away the finer materials, thus increasing the average size of the remaining grains.

While no intensive mineralogical work has as yet been done, rapid examination of these sands under the binoculars would seem to show that certain minerals are characteristic of certain stretches of the coast. Thus along the Long Island coast the sands are very rich in red garnet, and along the New Jersey coast in limonite-coated glauconite. A sofar unidentified black mineral likewise occupies an important place in the majority of North Carolina sands.

Serpentine Marble Deposits of the Maryland-Pennsylvania Area. W. F. PROUTY.

The area between Baltimore and Philadelphia has many deposits of serpentine. The greatest development of these is in the neighborhood of Conowingo.

All the serpentine deposits studied in this area appear to have been derived from basic igneous rock. In all these deposits a talc border is present and some of the larger deposits change to a less serpentized greenstone toward the southwest, a little more removed from the larger bodies of more recent igneous work.

In places these serpentine bodies are lighter green than elsewhere. There seems to be a distinct relationship between this color and the more acid rock border. The light color occurs on the side of the acid igneous or metamorphic rock and away from the basic igneous rock border.

The smaller serpentine deposits have as a rule less structural unsoundness than the larger ones and therefore are better as quarry sites.

Structural conditions in all these deposits are very complex. It is necessary for successful quarry operation that the structural conditions govern the quarry method. In one of the quarries of this region a radical shift in the operations to make them conform to structural unsoundness doubled the output of sound blocks.

There are many pegmatite dikes in this area. In all cases where those acid dikes cut the serpentines, they have lost silica to the serpentine. As a result there have been formed duplicate bands of hydrous silicate minerals inside the serpentine walls. In the larger replacement bodies the mineral sequence away from the serpentine is: talc, actinolite, chlorite, feldspar (usually a soda spar). Small offshoots from the pegmatites seemingly higher in aqueous solutions and silica gave pure talc veins.

The investigation supports the contention of Professor Esper S. Larsen that these mineral deposits are due to active hydrothermal alteration rather than simple desilication of the pegmatites, since there is a higher silica enrichment than could result from a desilication of a static pegmatite mass.

The Moss Flora of Durham and Vicinity. H. L. BLOMQUIST.

This paper was a preliminary report of the mosses occurring within a radius of about fifteen miles with Durham as a center. One hundred species more or less were reported. While the author had made many of the identifications himself, specialists on mosses had been consulted in all cases. The outstanding finds were, *Tortula pagorum* (Milde) De Not, not reported before from North Carolina, and *Hygroamblystegium orthocladon* forma *brevinerva* n. f. Grout, apparently new to North America. The relation of mosses to habitat was also discussed.

A Simple Technique for the Preparation of Articulated Skeletons of Small Vertebrates. W. C. George.

The dead bodies of the animals to be used (the smaller varieties of salamanders and frogs) are placed in an aquarium containing small young tadpoles. The tadpoles suck away the flesh in the course of a few days. There is left the skeleton, frequently enclosed in more or less of a bag of skin. The skeleton is then fished out of the aquarium (the skin is removed if any is present), stained, dehydrated, and mounted in balsam under a cover-glass. The skeletons should be kept under casual observation while they are in the aquarium so that the process may be stopped before the ligaments have been sucked away.

Preparations made in the above manner have been found useful for

the study of comparative osteology, and, in the case of young animals, for demonstrating ossification centers.

Some Properties of Transon's Auxiliary Parabola. J. W. LASLEY, JR.

Abel Transon showed in 1841 that the axes of the penosculating conics of a plane curve envelop a parabola. He gave a construction for this parabola and stated some properties of it. He used the axis of aberrancy and the osculating parabola. The present paper gives a construction depending on neither of these concepts and states further properties of Transon's parabola. It is found that the axis of Transon's parabola is tangent to the osculating parabola at the vertex of the latter if, and only if, the original curve is a certain logarithmic spiral. That the directrix of the osculating parabola is the axis of Transon's parabola in case the original curve is a certain other logarithmic spiral. A relation between Transon's parabola, the ellipse of minimum eccentricity and the osculating equilateral hyperbola is pointed out. The equation is obtained for the penosculating conic whose axes touch Transon's parabola at the end of its latus rectum.

The Euler Condition for a Problem in the Calculus of Variations. ERNEST L. MACKIE.

An isoperimetric problem is considered in which the quotient of two definite integrals of arbitrary functions of a certain class is to be minimized, while a third definite integral is to be kept constant. The first necessary condition is shown to be analogous to that for the classical isoperimetric problem of minimizing a single definite integral.

The Stieltjes Integral in the Theory of Probability. E. R. C. MILES and F. G. DRESSEL.

Given the bounded and closed set E. If we denote by p(e) the probability that P is in the subset e of E, with $p(E) = 1$, then we may define the average value of f(P) as the Stieltjes integral of f(P) with respect to p(e), extended over E. This definition includes both the discrete and the continuous cases. The proofs of the standard theorems relative to the mean values of sums and of products are obtained directly as properties of the integral.

On the Expression of an Integer as the Sum of an Arithmetic Series. L. E. BUSH.

It is a well known theorem in elementary number theory that the necessary and sufficient condition that a positive integer be expressible

as the sum of consecutive positive integers is that it be not a power of two. T. E. Mason, in the American Mathematical Monthly, Vol. XIX, p. 46, gave formulas for the number of ways in which such expression is possible, and also for the case where consecutive positive and negative integers and zero are admitted.

In this paper the number of ways in which a given integer can be expressed as the sum of an arithmetic series of integers with a preassigned common difference is considered, and formulas are derived for this case and also for the case where only positive integers are admitted in the series. Several obvious specializations are made of these formulas and, in particular, the results mentioned in the first paragraph are easily obtained.

The most interesting feature of the results is that where both positive and negative integers and zero are admitted in the series, the number of possibilities of expression is independent of the magnitude of the common difference, depending only on whether it is an even or an odd number.

The Characteristic Roots of a Matrix. E. T. BROWNE.

If A is any square matrix of order n and I is the unit matrix the equation in λ obtained by equating to zero the determinant $|A - \lambda I|$ is called the *characteristic equation* of A. The roots of this equation are called the *characteristic roots* of A. Although no definite statement can be made as to the nature of the characteristic roots of the general algebraic matrix A, several authors, including Bendixson, Hirsch and Bromwich, have given upper limits to the roots. Some of these upper limits are given in terms of the matrix itself, while others are given in terms of the characteristic roots of auxiliary matrices. In this paper the author gives an upper limit in terms of the elements of the matrix itself, which for the general complex matrix can never give wider limits and usually gives narrower limits than those of Hirsch and Bromwich. The theorem, the proof of which is very simple, is as follows:

Theorem: If S_i (T_i) is the sum of the absolute values of the elements in the ith row (column) of a square matrix A, and if S (T) is the greatest of the S_i (T_i), the absolute value $|\lambda|$ of a characteristic root λ of A cannot exceed $(S + T)/2$.

From the theorem there are derived as corollaries upper limits to the numerical values of the real part and of the imaginary part of λ. Hirsch's and Bromwich's criteria follow as special cases of the criteria here given.

The Relation Between Molecular Structures and Absorption Spectra. E. K. PLYLER.

The results found from infra-red absorption measurements indicate that all materials containing carbon and hydrogen have absorption bands in the region of 3μ and 6μ.

Many of the observed bands have been classified as overtones and combination bands and similar characteristics have been found in the spectra of many different materials.

The Relation Between the Intensity and Position of the Overtones of Some Organic Liquids. P. E. SHEARIN and E. K. PLYLER.

A theoretical study of the intensity relations of the overtones of some organic liquids has been made with a view of determining whether there exists a relation between the intensity and position of overtones. A brief summary of some of the work that has been done by other observers is included. By the graphical method the intensities of the first and second overtones of some liquids were measured. These results, together with the ratio of the intensities of the first and second overtones and also a list of the products of this ratio times the correction factor, x, are given in a table. Values are also listed for three diatomic gases, the intensities having been obtained by other observers and the ratio of these intensities times the correction factor being calculated in this work. For both the liquids and the gases the product of the ratio of the intensities of the first and second overtones and the correction factor, x, is of the same order of magnitude and in consideration of the errors involved appears to be constant.

The Absorption of Light by Certain Fluorescent Dyes. H. W. STEPHENS.

The object of this work is to make a study of the absorption of certain fluorescent dyes during the time of evaporation. Eosin was used and allowed to evaporate from a fairly dilute solution of eosin alcohol collodion to a dry film of eosin collodion. Rhodamin-B was also photographed as a check of the method against the work of Speas and Dixon. In order to do this a Gaertner quartz rotating sector was used in conjunction with a Hilger E 1 quartz spectograph so that two spectra passing through two different solutions could be photographed at the same time.

The theory of fluorescence involves the Bohr equation which was developed for the hydrogen atom. Baly's theory of absorption and emission of phosphorescent and fluorescent substances was given and its relation to observed facts shown.

The apparatus consisted of an Ediswan Pointolite, a Gaertner rotating sector and a Hilger E 1 spectrograph, all of which instruments have quartz trains.

The bands were found to shift toward the long wave-lengths as the solution dried. This continued to a certain point, after which the shift reversed. The relative value of the absorption was found to change in the same way: it increased with time but returned to a minimum for the dry film. These changes were found to be gradual and continuous during the time of evaporation.

The Determination of Current, Frequency, and Pressure Relationships for Initiating and Maintaining the Electrodeless Glow Discharge. MILTON L. BRAUN.

The relation between the current necessary to start an undamped wave electrodeless glow discharge and the pressure shows a critical point for each wave-length between 90 and 160 meters. For hydrogen, nitrogen, oxygen, and carbon dioxide the critical current, I_c, and the critical pressure, P_c, are found to bear the simple relationship,

$$I_c = k P_c$$

The critical current is also found to vary inversely as the square of the frequency of excitation and hence is expressed by the equation,

$$I_c = a\lambda^2 + b$$

λ being the wave-length in meters. The constants, a and b, have been evaluated for the above mentioned gases. Critical pressures calculated from these equations are in harmony with the experimentally determined values.

The Photometric Characteristics of the Electrodeless Discharge in Air and Mercury Vapor. M. D. WHITAKER.

A spherical bulb containing air and mercury vapor was placed in a solenoid carrying high frequency currents of damped amplitude. The visual intensity of the resultant discharge was studied under various conditions of pressure frequency, and current. The visual intensity of the discharge was compared with an arbitrary standard by means of a flicker photometer. No simple relation was found to exist between visual intensity of the discharge and pressure, current or frequency, but consistent irregularities were observed. The visual intensity of the discharge had a maximum value at a pressure of about 3 microns for

all values of the exciting current, but the minimum measurable intensity shifted from higher to lower pressure as the exciting current was decreased. Periodic breaks were found to exist in curves showing visual intensity as a function of exciting current. Maximum values of visual intensity were found to exist when excited at wave-lengths of 252, 358, and 490 meters.

Relative Intensities of Arc and Spark Lines of the Electrodeless Discharge in Mercury Vapor. O. P. HART.

The purpose of this investigation was to determine the relationship, with other factors constant, between (1) intensity and pressure; (2) intensity and potential; and (3) intensity and excitation frequency for arc and spark lines of mercury in the electrodeless discharge.

Excitation of discharge took place in a 12.5 cm. spherical bulb surrounded with a helical coil of 25 turns of heavy copper wire when the latter was supplied with damped high frequency current.

Three sets of spectrograms were taken. (A) Intensity as a function of pressure with temperature, potential, and excitation frequency constant. (B) Intensity as a function of potential with temperature, excitation frequency, and pressure constant. (C) Intensity as a function of excitation frequency with temperature, pressure, and potential constant.

The intensity-pressure spectrograms disclosed a maximum intensity for arc lines at 8 microns. The spark line intensity increased exponentially. The pressure spectrograms are recommended for study of the mutual influence of arc and spark spectra. They are also recommended for detecting and quantitatively measuring the amount of impurity in a substance.

The intensity-potential spectrograms, besides showing the intensity distribution of arc and spark lines with varying potential, disclosed a method of easily distinguishing between spectra from atoms according to the degree of ionization.

The Effect of External Resistance in the Plate-Filament Circuit of Radiotrons. K. Z. MORGAN.

Resistance of several megohms was placed in the plate-filament circuit of various types of radiotrons and curves were obtained showing the relation between plate-filament current and the total e.m.f. in the circuit. It was found that as the e.m.f. was increased from zero over a certain range, the current increased, giving a straight line curve whose slope

was slightly less in magnitude than that of the external resistance. However when certain critical ranges e.m.f. were reached, there was a sudden vertical drop in the curve, indicating zero resistance. When the e.m.f. was again increased after the loss in current from the plate to filament, there was as before a steady increase in current. This second portion of the current-potential curve was usually nearly parallel to the first and crossed the coördinate of zero current at a point D (where the current-potential curve would cross in its second upward bend if there were no external resistance in the circuit). The e.m.f. was then decreased and the second portion of the curve continued toward zero potential until another vertical jump indicated zero resistance. This second line of zero resistance connected the second portion of the curve again with the first and proved that the current which was formerly lost from the plate had now been regained.

The second line of zero resistance always occurred at an e.m.f. less than the first. The length of each line was increased with the grid potential, and the difference in potential between each line was increased with the external resistance in the circuit. By applying Ohm's Law to the circuit it was found that each line of zero resistance occurred when the potential across the tube was such that the tube had excessively high resistance. Over each range of zero resistance there was an instantaneous change in potential of several hundred volts across the plate and filament.

If the external resistance was large, the jump was to a negative potential and if small to a positive potential. Hull concluded that the potentials of stability, when high external resistance was placed in the plate filament circuit, were zero and a potential slightly less than D. This experiment verifies the last statement, but seems to indicate that the first point of stability may vary widely from zero.

A Note Concerning the Diffusion of Gases. CHARLES W. EDWARDS.

It has been the practice of teachers of physics to demonstrate molecular motion and to give the student some conception of molecular velocities by sprinkling on the lecture table a little ammonia or other volatile liquid and ask him to note the short time required for the odor to reach the back of the room. This experiment is suggested in several representative textbooks.

Observation of vortex rings, cigarette smoke rising in the air and the very long time required for uniform pressure to be attained in a high vacuum when the air pump is going, leads one to the conclusion that the

phenomena described in the texts is probably entirely due to convection. Experiments conducted under conditions in which convection currents are of very slight effect seem to justify the belief that the coefficient of diffusion for air and CO_2 is about a millimeter a second. More accurate determinations are in progress.

The Absorption of Sulphur Dioxide by Calcium Phosphates. FRANK K. CAMERON.

This work is a continuation of the investigation upon which W. M. Mebane reported last year to this Society, and described in detail in the Journal of Physical Chemistry, Volume XXIII, pages 961–969, July 1929. The work has been made possible by the Robert Ober Fellowship, inaugurated by Ober Sons and Company through its President, Mr. Gustavus Ober. Mr. Hughes, the holder of the Fellowship, has shown marked ability, particularly in the designing and assembling of the necessary apparatus. These assemblies will be described at another opportunity, the present purpose being to report progress in the results attained.

The work may be conveniently described under three headings:

(1) Working with pulverized phosphate rock containing small amounts of adsorbed water, at pressures from one to two atmospheres, it was found the absorption of sulphur dioxide took place best at a temperature of about 450°C. The absorption follows, approximately, the equation for a monomolecular reaction. About two thirds of the phosphorus is transformed to "citrate soluble" form.

(2) Working with precipitated tricalcium phosphate at lower temperatures, it is found the absorption of SO_2 is most satisfactory at about 60°C. Again the conversion to "citrate soluble" is approximately two thirds of the phosphorus.

(3) The results above stated, while far better than noted by any previous investigator, are not suggestive of any possible economic utilization. Preliminary experiments showed that if the tribasic phosphate be shaken with a mixture of *liquid* sulphur dioxide and water, a good separation of the lime and phosphoric acid can be secured, the aqueous solution containing the lime and most of the phosphorus in the ratio corresponding to a mixture of primary and secondary calcium phosphate; a solid is formed of a very basic phosphate; and the liquid sulphur dioxide contains very little of either lime or phosphoric acid. Investigation of this reaction and the necessary study of the vapor pressures involved are under way, and the data now reported will be much extended before the formulation of a plant process is undertaken.

THE CORPUSCULAR THEORY OF RADIATION AND THE WAVE THEORY OF MATTER[1]

By J. B. Derieux

Introduction

The most fascinating topics of recent physics are, I believe, the corpuscular theory of radiation and the wave theory of matter. I thought that you might enjoy an elementary survey of them tonight. I shall discuss only those portions which I think I am able to make clear to everyone present.

The Corpuscular Theory of Radiation

Light

In the latter part of the 17th century, Newton advanced the corpuscular theory of light, while Huygens, his contemporary, advocated the undulatory, or wave, theory. Any theory as to the nature of light must be able to explain its rectilinear propagation and its refraction, or change in direction when passing obliquely from one medium to another.

Let us consider the refraction first, and let it be a case of a ray passing obliquely from air into water, where it is bent in a more downward direction. By the corpuscular theory, this is explained by the assumption that the corpuscles are attracted downward by the water as they near its surface, and thus their velocity is increased in the downward direction. Their horizontal velocity is unchanged, as the attraction is the same in both directions that way, and thus the direction of the particles will be more downward in the water. (This is analogous to the case where a stone is thrown obliquely to the earth.) When the particles have entered the water a short distance, the attraction of the water which is then above them equals that from below, and the corpuscles then travel in straight paths. This is a very plausible explanation, is it not? Notice that since the downward velocity is increased and the horizontal remains unchanged, the velocity of light will be greater in water than in air.

[1] Presidential address delivered before the North Carolina Academy of Science, May 9, 1930.

According to the wave theory, the bending results from the fact that the velocity of light is less in water than in air. The waves are across the ray, therefore, the lower end of each wave enters the water first, and being slowed down, the wave is swung around until the other end enters the water, then it moves in a straight direction. (An analogy to this is the case where a gocart, in being pushed along, is given a shove and let go obliquely across a concrete sidewalk into a grass plot. When the nearer wheel meets the grass, it is slowed down, and the gocart is swung around until the other wheel enters the grass, then the gocart moves in a straight direction, but inclined to that on the sidewalk.) This explanation of refraction also sounds reasonable does it not?

At the time when Newton and Huygens were propounding their respective theories, it was not known whether light moves faster in water or in air, and, therefore, any debates upon their theories based upon refraction were, like our radio debates, no decision affairs.

The absolute velocity of light through space had been determined by Roemer from the eclipses of the moons of Jupiter, and its enormous value was possibly considered in favor of the corpuscular theory. Of undulation speeds then known, that of sound is only about one fifth of a mile per second, and water waves only a few feet, while light has the value of 186,000 miles per second. It could travel seven times around the earth in a second, and then have to wait a little while for the tick. It probably seemed unreasonable for wave speed.

Now let us consider the arguments on the rectilinear propagation. That light travels in straight lines is evident since objects are in the directions in which they appear to be, and bodies cast sharp shadows in the sunlight, for example. Everybody knows that projectiles travel in straight lines, barring gravity, and are screened off sharply at the edge of barriers in their path, while the undulations of water and sound bend around behind bodies in their path. For example, when you are behind a building you may hear sounds that are produced on the other side of it. The corpuscular theory certainly sounds more reasonable here.

It is said that Newton accepted the corpuscular theory because of its supremacy in this latter field. You remember it was a draw between the two theories in refraction. Because of Newton's prestige, most of the other physicists accepted his judgment. Sources emitting light, such as flames and incandescent bodies were considered as throwing of light particles, called corpuscles, which entered the eye when it was turned in their direction, and thus gave the sensation of light. Objects which do

not emit were supposed to be made visible because some of the light corpuscles which fell upon them bounded off and entered the eye, carrying the characteristics of the bodies with them. Light sojourned in a corpuscular garb for about 150 years.

At the end of that time, which was about the middle of the 19th century, Foucault devised a means of measuring the relative velocities of light in water and in air. His results showed, without a doubt, that its velocity in air is the greater, and the wave theory, then and there, took the ascendency and has held it ever since.

Fraunhofer devised the diffraction grating by which he actually measured the wave-length of light, and that solidified the wave theory. I shall discuss the theory of the grating here, as I want to refer to it a little later. A diffraction grating is a plate having slits in it through which light can pass. If a beam of monochromatic light is caused to fall perpendicularly upon it, and the part which passes through the slits received upon a screen which is parallel to the grating, it is found to be broader than the primary beam and to have bands of maximum and minimum of illumination across it, parallel to the slits.

In explaining the result, let us consider only two of the slits so as to simplify the discussion. According to wave theory, secondary wavelets are started at the slits by the primary beam, and these spread out in concentric circles just as if the light had originated at those points, the two wave trains intermingling with each other. (By wave trains is meant a series of waves one after the other just as a railway train is a series of cars.) On the screen midway between the slits is a bright band, because it is at the same distance from both slits, and, therefore, the same number of wave-lengths from each, hence the two wave trains which started simultaneously, will agree, the crests and troughs of one falling on the corresponding parts of the other, thus reinforcing each other and producing a maximum of illumination. A little to one side of this is a point which is one half of a wave-length farther from one slit than from the other, and there the crests of one train fall on the troughs of the other, the two trains thus opposing each other and producing a minimum of illumination. A little farther out yet, and there is an entire wave-length difference in path, and at that point there is a another maximum of illumination. Other maxima and minima occur as you pass on out across the beam. If there are several slits, the maxima are narrow lines. From similar triangles which may be drawn upon a diagram representing the apparatus, it can be seen that the ratio of the wave-length to the slit spacing is equal to the ratio of the distance

between the first two maxima mentioned to the distance the screen is from the grating. Thus the wave-length can be determined.

When the value of the wave-length is considered, it is no wonder that it was so long before a method for measuring it was devised. The wave-length of sound, middle C, is about two feet, that of water several feet, while light waves have a length of only about 2/100,000 of an inch. It requires about 250 of them to reach the thickness of this sheet. The lines on the gratings must be so close together that there would be about ten of them cut along the edge of this sheet.

Roentgen Rays, or X-rays

Closing the discussion on light for the present, let us next consider Roentgen rays. Roentgen discovered X-rays in 1895. Their character being unknown, they were designated by X, as the unknowns of algebra are. Their bullet-like penetration of matter which was opaque to light, and the failure of gratings to analyze them into waves, soon placed them in the corpuscular class. But Laue in 1912 conceived the idea of using as a grating for them, the equally spaced layers of a crystal. It was tried, and the corpuscular theory of X-rays vanished. Their wave-length is too short for the ruled grating to solve. It is about 1/1000 that of light. Yes, Roentgen rays are in the form of waves.

Becquerel Rays

Becquerel rays, the rays from radioactive substances, were discovered in 1896 by the person whose name they bear. They, too, were considered as corpuscular. They are of three kinds, termed alpha, beta, and gamma. The gamma rays have succumbed to the wave test, but the alpha and the beta rays are still corpuscular.

The Quantum Theory

We shall need to survey the quantum theory or radiation for just a minute or two, in preparation for what is to follow. Plank founded this theory in 1900. It asserts that no radiation is continuous in time or direction, but takes place in pulses or bundles, each bundle carrying an elementary quantum of energy. The total radiation is an integral multiple of this elementary unit, just as a total amount of electricity is an integral multiple of the electron. The quantum as a unit, however, differs from the electron, in that while a quantum is constant for a given

frequency of radiation, it is different in different frequencies, its value in any case being equal to the product of the frequency and a universal constant known as Plank's constant. Expressed in the form of an equation, $E = h\gamma$, where E is the quantum of energy, γ, the frequency of the vibration in the radiation, and h, Plank's constant.

The quantum theory has been beautifully verified in the action of X-rays and ultra violet light. They have the property of throwing out electrons from substances upon which they fall. The energy of the ejected electrons, which evidently is transferred from the radiation, is proportional to the frequency of the radiation ejecting them. Hence, the energy of the radiation must be proportional to its frequency. And it is not a continuous process, though the radiation may appear continuous, for if the exposed surface is small enough, as in the case of a mercury droplet where I have observed it, there is an appreciable interval between electron ejections, thus indicating that the radiation is in bundles. This bundle property is demonstrated again where the surface is placed at different distances from the radiation source. At the farther distances where the radiation has spread out and is fainter, the electrons are thrown out with the same speed as when the surface is close, showing that while the bundles per unit area are fewer, each bundle which strikes an electron holds together, carrying its quantum of energy. In the case of X-rays, the ejected electrons in any case have approximately the same energy as the electrons which produced the X-rays by bombardment in the X-ray bulb. This looks as though the primary electron, when it is arrested by impact, throws out its energy in a compact form, like a bundle, to travel out until it can hand it over to another electron.

Yes, the indications are that all radiation is intermittent and in bundles. A light source which we may consider as shining continuously is blinking all the while and that in concentrated bundles.

The Atomic Theory

Permit me to refresh your minds on the atomic theory, as I shall refer to it a little farther on. Blamer, in 1885, observed that the wavelengths of the lines which had then been measured in the visible spectrum of hydrogen were not haphazard, but were at regular intervals, and if arranged in order, formed a series. (A group of numbers such as 3, 6, 9, 12 is called a series.) He composed a formula for calculating the wavelengths, which agreed not only with the ones which had then been measured, but predicted others which were later measured. This is known as the Balmer series. Other series were later observed and formulated.

Bohr, in 1913, considering the spectral series of wave-lengths, devised an atomic model to account for them, which is based upon the quantum theory of radiation. This model has a nucleus of positive electricity, around which circle electrons of negative electricity in orbits, like the planets of our solar system go round the sun. However, only certain orbits were permissible for the electrons. They are the ones in which an electron would have energy which is an integral multiple of the quantum. The smaller orbits corresponding to less energy, an electron may drop from one orbit to a smaller one but in so doing it must give up, in the form of radiation, the excess of energy of the orbit which it leaves over that of the one to which it drops. That will, of course, be an integral multiple of the quantum. The frequency of the emitted radiation will be equal to the emitted energy, divided by Plank's constant, as previously stated in regard to the quantum theory, the emitted energy being equal to the difference between the energies of the two orbits. Expressed in the form of an equation, $\gamma = (E_1 - E_2)/h$ where γ is the frequency, E_1 and E_2, the energies, and h, Plank's constant. If it drop between adjacent orbits the radiation will have one frequency, if it drop across two orbital spaces, the radiation will have a frequency one step higher, etc., and thus the series is formed.

The Compton Effect

When X-rays fall upon matter, they are scattered in all directions, and their frequency is reduced from that of the incident beam. The reduction shows a gradual increase in amount as the angle between the direction of incidence and that of the observed scattered rays is increased. According to the quantum theory this reduction in frequency results from a loss in energy. Compton boldly applied the extra quantum theory to the phenomenon. He considered a bundle of X-ray energy as having mass, its energy being due to its velocity, and that when it bumps into an electron in the scattering material, it loses energy to the electron, just as any finite body does in impact. He computed what the loss in energy would be at different angles, on that assumption, and the consequent reduction in frequency, made careful observations of the reductions, and, lo! the computed and observed values were in almost perfect agreement. And, then X-rays as corpuscles came to life again. The electrons which receive the energy from the X-ray corpuscles have since been observed, as they recoil from the impact. This phenomenon is known as the Compton effect.

The Raman Effect

And then, to cap it all, Raman of Calcutta, in 1928, succeeded in observing the same effect with visible light which is scattered, and—light is again corpuscular. The scattering of light is a very, very common phenomenon, for without it, only bodies which are luminous would be visible at all. If scattering were suspended in the daytime, the appearance would be that of night; the only objects visible, except as silhouettes, would be the sun and stars, the planets too being invisible. In this scattering, however, there is no change in wave-length. The sky is visibly blue, because of the scattering of the sunlight by the particles in the atmosphere, but this, again, is not because of change in wave-length. It is because the particles are so small that they can scatter only the shorter waves, which are the blue ones, the longer ones, predominated by red, pass on through. This same explanation suffices for the red sunset, where we receive the direct sunlight, or rather the remains of it after the blue has been scattered from it. But, I repeat, in this there is no change in wave-length of the light which is scattered. If sunlight were pure red, the sky would be black. Scattering without change in frequency is explainable by either wave or corpuscular theory.

Raman made his discovery of the change in wave-length in scattering by observing the light which is scattered by the molecules of a clear liquid when light of only one wave-length is passed through it. His incident light was that from a spectral line of the mercury arc, and when he photographed the spectrum of the scattered light he found lines of a different wave-length or frequency. This change in frequency, according to the quantum theory, corresponds to a change in energy which, similar to the Compton effect, must result from the collisions of the corpuscles of light with the molecules of the liquid. This phenomenon is known as the Raman effect. Light is, then, corpuscular.

So now we are confronted with X-rays and light as corpuscles again. It has been known for a good while that light exerts a pressure upon a surface where it falls, just as a stream of water from a hose. If a beam of light were strong enough it would knock a man down if it hit him. Of course, it would require a very strong beam, stronger than any that we will probably ever be able to produce. The weight of the light issuing from a 50-horsepower searchlight in 100 years is 1/20 of an ounce, but—it is traveling with a speed of 186,000 miles per second. The theory of relativity has been contending for some time that light has mass, the demonstration of it being that its direction of motion is changed by

a gravitational field. The observations upon the change in direction of the light from a star as it passes a planet have been made, and the theory seems verified.

Diffraction by the Corpuscular Theory

While it may be possible to explain some of the phenomena of radiation by the corpuscular theory, how can the action of a diffraction grating be explained by it, you may ask. To do this, it is necessary to endow the corpuscles with a little intelligence, or intuition. You remember that the light from a grating is brighter in certain directions than in others. This, in the corpuscular theory, corresponds to more corpuscles going in these directions than in the others. It is explained on the theory of probabilities. The probability of each corpuscle's going in the former directions is greater, therefore, more of them go in those directions. But you remember that the directions of the maxima are changed with the distance between the slits. Then, when a corpuscle is passing through a slit how is its direction of greatest probability controlled by the distance to the next slit? Here is where the intelligence idea must be introduced, the corpuscle must "know" how far the next slit is away, that is, the corpuscles must have some form of intelligence.

When we stop to consider, it is not so difficult to concede it in this case, since they have been granted it in others. As an example, let us consider this campus as of a uniform surface all over and with no obstacles upon it. If we were to select a freshman boy and tell him to run from here to the girls' dormitory as quickly as possible, but that he must touch the stone wall at Main Street on his route, do you suppose that he would know what route to take so that the distance would be the shortest possible? He probably has learned that a straight line is the shortest distance between two points, but would he know where to meet the wall? If the wall were a mirror and we should direct a corpuscle of light to make the journey, it would not hesitate on what route to take for the shortest distance. It instantly "knows" it in any case and always takes it. In this case it is the one which approaches the wall at the same angle at which it recedes.

Or again, suppose the journey to be made is from here to the new campus, and that the speed beyond the wall is to be one half of what it is on this side. The boy would probably select a straight line between the points, and again the corpuscle would show the more intelligence.

It would meet the wall farther west than the straight line, more nearly north of its terminus, which would give it more of the distance in the fast territory and less in the slow. This corresponds to refraction. Yes, it probably is not unreasonable to concede the corpuscles the necessary intelligence for their behavior in connection with the diffraction grating.

Other phenomena of X-rays and Light could be explained by the corpuscular theory if there were time for it, but we must go to the other topic of our discussion. In closing this one, let us say that since the evidences are good as to the corpuscular nature of X-rays and light, it is very probable that it exists in the radiation of longer wave-lengths, such as heat and radio. Therefore it would seem that the corpuscular theory might be applied to all forms of radiation.

THE WAVE THEORY OF MATTER

Electrons as Waves

The indications that radiation is in the form of corpuscles, is not the only thing that we physicists have to worry over now, for Davisson and Germer have succeeded in showing that electrons are wave-like in character. This they did in 1927. Directing a stream of electrons against a crystal grating the reflected electrons formed a "spectrum," that is, their effect was greater in some directions than in others, just as it is with light and X-rays. Then knowing the direction of a maximum and the distance between the layers of the crystal the wave-length can be calculated.

According to the quantum theory, wave-length and momentum are related to each other in such a way that the wave-length equals Plank's constant divided by the momentum; momentum being the product of mass and velocity. Expressed in the form of an equation $\lambda = h/mv$, where λ is the wave-length, m, the mass, v, the velocity, and h, Plank's constant. The mass of the electron is known and its velocity can be computed from the voltage through which it falls. Thus the theoretical wave-length can be determined, and it is in good agreement with observed values. You notice that the wave-length changes with the speed, being less with higher speeds. This too, they verified. For the 50-volt electron the value for the wave-length is 15/100,000 cm. or 6/100,000 inches. It is about three times that of the mean wave-length of light. Shall we say that a 50-volt electron makes waves which are of this

length? No, that it *is* waves of this length. Now, when we think of an electron moving, it is proper to conceive of it as an isolated group of waves squirming along.

Hydrogen Atoms as Waves

As a further step in the field of waves, Dempster has, within the past six months, succeeded in getting a "spectrum" of hydrogen atoms in a similar manner, and thus the hydrogen atoms become waves. The American Association for the Advancement of Science at its December meeting last year awarded him a thousand dollars for his achievement. Now when the chemists think that they have a liter of hydrogen molecules, they have only a liter of hydrogen waves. The wave-length of a hydrogen molecule, also, changes with speed. At its speed of normal thermal agitation its theoretical wave-length is 1/10,000,000 cm. or about 1/1000 of the electron.

Matter as Waves

Having gone thus far in the discovery of waves of matter, it seems to indicate that all matter is composed of waves. The physicists are climbing onto the band wagon fast, and courses in wave mechanics are in demand. We are told that even our bodies are composed of waves. The wave theory may serve the sociologists, too, helping them to explain why our young people like so much to dance—it is in reality just in them. As we have said, the wave-length of a body decreases with increase of velocity or mass, so that when a heavy body moving rapidly is considered, the waves are too minute to be detected by present methods. For example, the wave-length of a golf ball, which weighs 1/10 of a pound, or 54 grams, moving 1/10 of a millimeter per second is 10^{-26} cm.

When the theory of the atomic composition of matter, stating that all matter is composed of minute particles called atoms, was first proposed, it was hard to grasp it. Just about the time that people were getting complacent over it, along came the theory of atomic structure which states that the aforesaid atoms are not ultimate but are composed of minute charges of positive and negative electricity. Then we thought that we were at the bottom, but now comes along the idea that the electrons, themselves, are waves. We simply stand in awe and ask, what next?

Fusion of the Corpuscular and Wave Theories

Thus we have the corpuscular and wave theories in both radiation and matter. Now you are probably wondering what we are going to do about it. Well, both theories are well backed up by experiments and both have good features. In many cases the one complements the other, therefore both of them are being retained, and in any problem the one is used which makes the solution easier. Further efforts are being successfully made to fuse the two theories.

As an illustration of how one theory aids the other, let us consider Bohr's atomic model which was previously outlined. The stable or permanent orbits have always been a mystery. Just why an electron can revolve in certain orbits and is barred from others between, has been a dark question. Wave mechanics clarifies this point by suggesting stationary waves for these orbits. If one end of a cord is attached to a prong of a tuning fork and the cord drawn tight, when the fork is set into vibration the cord will, in general, be shaken to and fro with an apparently troubled disturbance. But if the length of the cord is properly adjusted, a stationary pattern of nodes and loops will appear in it. The loops are the enlarged portions and the nodes the constricted ones. Its state is like unto that of a spinning top which is "asleep." For this to take place the length of the cord must be an integral multiple of half a wave-length. If the length of the cord is changed, it becomes troubled again and will not be steady until another definite length is reached which is another integral multiple of half a wave-length. The same applies to the air column in a tube which resonates when a tuning fork is held above it, and its length properly adjusted, as is known from a standard elementary experiment in physics. The wave-theory of matter pictures the stable orbits of the electron as those in which the length of the orbit is such that the electron waves will form a stationary pattern of nodes and loops in it. Thus the wave theory comes to the aid of the corpuscular theory and unravels the mystery of the stable orbits in the atomic model. It does not set up a new model.

Another perplexity of the atomic model has been the frequency of the radiation from it. It is different from any that is within the atom, and how an atom can give out a frequency which it does not possess is hard to understand. According to the quantum theory, the frequency of the radiation when the electron drops from one orbit to another is equal to the loss in energy divided by the radiation constant, as you remember. Expressed in the form of an equation, $\nu = (E_1 - E_2)/h$,

where E_1 and E_2 are the energies in the orbits. This is entirely different from the frequencies corresponding to the orbits themselves, they being E_1/h and E_2/h. For example if the energies of the orbits were 100 units and 60 units, and the radiation constant were 5, then the frequency of the radiation, according to the quantum theory, would be $(100 - 60)/5$ or 8, while the frequency of the orbits would be 100/5 or 20 and 60/5 or 12, both of which differ from the radiation. Why it is thus is perplexing.

Wave mechanics offers the suggestion that the radiation frequency is the beat frequency of the frequencies of the two orbits. When two tones which differ slightly in frequency are sounded simultaneously, as for example two tuning forks, there is a rhythmic swelling and fading heard in the sound. These are known as beats. A swelling is produced each time that the vibrations of the two forks coincide, and a fading when they are opposite. Therefore, a beat will be completed each time that the faster fork gains one vibration on the other. For example if one fork has a frequency of 210 vibrations per second and the other 200, then the faster one will gain 10 on the other in 1 second, therefore, the beat frequency will be 10, which you will notice is the difference in the frequencies.

Now in case of the atom under discussion the frequencies of the orbits were 20 and 12, therefore the beat frequency would be 8, which is the frequency of the radiation. This may be seen from the general expression, too. The frequency of the orbits are E_1/h and E_2/h. The beat frequency is $E_1/h - E_2/h = (E_1 - E_2)/h$ which is identical with the frequency of the radiation. So again the wave theory comes to the aid of the corpuscular.

Corpuscular Speed and Wave Speed

Davisson and Germer's results indicate that when an electron beam goes obliquely from vacuum down into metal, it is refracted downward, which shows that the electrons considered as waves travel more slowly in the metal. But it is known that an electron passing from vacuum to metal has a higher speed in the metal. That is, the waves are slowed down but the corpuscles are sped up. Thus we see that a beam of electrons has two speeds. One when it is thought of as waves, and another when it is considered as corpuscles. There is apparently a great dilemma here. It turns out, however, that when we consider the corpuscular velocity as being that of the speed of the beats in the waves, the trouble vanishes.

Consider two wave trains of wave-lengths 1 cm. and 1.01 cm. travel-

ing along together but slightly out of step. At some point in their trains their crests will coincide, but at one wave-length distant they will be .01 cm. away from coincidence. At a distance of 100 waves they will coincide again and so on for each hundred. These points will correspond to beats.

If both wave trains travels with the same velocity the beats will have the same velocity as the waves. But this is seldom the case in nature, especially with light waves. The shorter of these travel more slowly than the longer ones in most substances. To consider what would happen in this case, imagine yourself riding along on the crest of one of the shorter waves, and the train of longer waves gliding by. When a crest of it is just opposite you, you are at a beat. When the faster train has gained .01 cm. on your train the beat has moved to the crest of the wave behind you, that wave being .01 cm. ahead of its mate in the other train when you started your observations. If a gain of .01 cm. moves the beat one wave back of you, a gain of 1 cm. will move it 100 waves or one meter back. If the velocity of your wave is 10 meters per second, and the other, 1 cm. per second greater, the velocity of the beats will be 9 meters per second, that is, (10 − 1) meters per second. As another illustration of this, consider two railway trains on parallel tracks, one having coaches 100 ft. long and the other 101 ft., their velocities being 1000 and 1001 ft. per minute, respectively. Imagine yourself standing on a vestibule of the slower train and that it is opposite the vestibule of the other. The rear vestibules will lack 1 ft. of coincidence; that of the longer coach being 1 ft. behind. One minute later these vestibules will coincide, the point of coincidence having moved back 100 ft. Therefore, the velocity of the "beats" will be 1000 − 100 = 900 ft. per minute.

This beat, or group, velocity is what is usually observed. For example if two tuning forks producing beats are used in measuring the velocity of sound between the two points, it would probably be observed upon the time for a beat to pass between the points, its passage being easily observed. If the two waves did not have the same velocity, the velocity of sound would not be obtained, but only the velocity of the beats. Another illustration is that of the velocity of the yellow sodium light which is the blending of two colors whose wave-lengths, are 5890 and 5896 Angstrom units. Its velocity is different from that of either of its components. Another excellent example is that of the determination of the relative velocities of light in air and in carbon bisulphide. As you are probably aware, by the wave theory a ray of light in refraction is bent in proportion to the relative speeds in the two media. Therefore

the ratio of the speeds may be determined by refraction. The value thus obtained for air and carbon bisulphide is 1.66. Michelson made a direct determination of the relative velocities by passing light through tubes of each. His value was 1.76. Here was apparently a bad disagreement, but the fact of the difference between the group and wave speeds was known at that time. Michelson had measured the group speed, while the wave speed had been observed by the refraction method. In the range of wave-lengths which Michelson used, it was computed that the group speed in carbon bisulphide was about 7 per cent less than the wave speed. Seven per cent of 1.76 is 0.12, subtracting this gives 1.64 which is in excellent agreement.

A calculation which we cannot give here shows that if the speed of a particle is considered as being that of the group velocity of the corresponding waves, the wave and corpuscular theories give identical results.

In closing let me briefly sum up the points which I have covered in the development of the corpuscular and wave theories. The corpuscular theory of light, advanced by Newton, held sway for about one hundred and fifty years, which was from the last part of the seventeenth century to the first part of the nineteenth. The wave theory then took the ascendency because the measurement of the relative velocities of light in air and in water favored it. The wave theory has been predominate now for about one hundred years, however the corpuscular nature of X-rays and light have just been revived by Compton and Raman. It is very probable that all radiation has corpuscular characteristics.

The electron has been shown to be wave-like in character by Davisson and Germer and the hydrogen atom has been shown by Dempster to be of a similar nature. It is only natural, therefore, to conceive that all matter is wave-like in character. The corpuscular and wave theories are being fused and aid, rather than contradict, each other.

CONCLUSION

The corpuscular theory of radiation and the wave theory of matter are in their infancy as yet, but their growth is rapid and they are giving indications of making valuable contributions to science.

Radiation and matter show both corpuscular and wave-like characteristics. Shall we say, then, that radiation and matter are corpuscular, only exhibiting wave characteristics at times; or that they are corpuscular at times and wave-like at other times; or that they are only waves exhibiting the corpuscular nature at times. This point is yet to be settled.

DUPLICITY AND OTHER ABNORMALITIES IN DIAMOND-BACK TERRAPINS[1]

By Samuel F. Hildebrand

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Plates 1–4

The literature does not contain many records of deformities and monstrosities in chelonia. It is thought by some writers that abnormalities, particularly such as double monsters, go unobserved because of the manner of breeding and nesting. It would appear to be of interest, therefore, to report those that have been noticed in diamond-back terrapins, as well as to cite some of the literature dealing with twinning in chelonia. Two closely related varieties or subspecies, Chesapeake and Carolina terrapins (*Malaclemmys centrata centrata* and *M. centrata concentrata*), have been propagated at the U. S. Fisheries Biological Station, Beaufort, N. C., over a period of 20 years. A third variety, the Texas terrapin (*Malaclemmys pileata littoralis*), also was used to a limited extent for several years. Over 55,000 young have been hatched and generally kept under close observation for several months and often for several years. The sand beds that are provided in the pens in which the eggs are laid and incubated are dug over after each hatching season. Young that fail to emerge from the sand then are found and unhatched eggs are uncovered and generally examined. It is highly improbable, therefore, that obvious external abnormalities are overlooked in the young that hatch, although irregularities of the embryos that die in the shell may not always be noticed.

The eggs are laid and hatched under conditions that are as near those used by terrapins in nature as it is possible to provide under artificial circumstances. The eggs are laid in sand beds, built slightly higher than the ordinary high tides and the eggs are left undisturbed, as deposited by the female, to be hatched by the heat of the sun. For a rather complete account of the plant used at Beaufort, N. C., for propagating terrapins the reader is referred to Hildebrand and Hatsel (1926) and for an account of the experiments conducted see Hildebrand (1929).

[1] Published by permission of the United States Commissioner of Fisheries.

Newman (1923, pp. 95–97), working with several species of fresh water turtles on Lake Maxincuckee, Indiana, found "a very large percentage of embryos abnormal in various respects: some with imperfect eyes; some with heads small and irregular; some with one or more feet lacking or tail lacking; some with deformed carapace; many with irregularities of the scute pattern of both carapace and plastron, and associated abnormalities." While somewhat similar irregularities have been noticed among diamond-back terrapins, they are, contrary to Newman's observations with fresh water turtles, quite rare.

The writer wishes to acknowledge his indebtedness to Dr. E. W. Gudger of the American Museum, to Dr. Bert Cunningham of Duke University, and to Dr. Waldo L. Schmitt of the National Museum for furnishing references to the literature on double turtle monsters and otherwise assisting the author.

Descriptions of the external anatomy of several specimens of double headed turtles appear in literature. However, the internal anatomy is not described or at most only mentioned in the accounts consulted. Duplicity is more nearly complete in the diamond-back terrapin described in this paper than in most of the specimens recorded in the literature.

The earliest record of a double chelonid monster that has come to the attention of the present writer is offered by Edwards (1751). This animal was a sea turtle and the author, although quite uncertain, thought that it was a hawk-bill. The place of collection is not mentioned. The author fails to describe the monster beyond a mere mention. The figure indicates, however, that duplicity had not proceeded far. The animal had two mouths and four eyes, but the heads were united beyond the snout and supported by a single, or more probably two united necks. According to the illustration the body was single and normal.

The next oldest record found is by Mitchill (1826) who mentions incidentally in a paper on two-headed snakes that he had heard of a "two-headed tortoise that lived to acquire a considerable size by taking food at both mouths."

Barbour (1888) published a rather extensive account of a double-headed turtle, *Chrysemys picta*, taken in the marshes of West River, New Haven, Conn. Barbour's article contains a full description of the external anatomy with excellent figures, showing both the dorsal and ventral aspects of the monster in comparison with a normal specimen. This article also contains an account of the animal's behavior.

The New Haven monster had two normal heads of equal size and a rather abnormally broad carapace, with a slightly curved vertebral line, but in other respects the structures appeared normal as in an ordinary terrapin. The heads behaved independently and according to the author differed in temperament.

Barbour (1896) gave a second account of the same animal, adding the information that the monster died from an injury, having lived from the first of June to the middle of September. The author, for reasons not stated, gives no account of the internal anatomy which he promised in his previous article and to which he appeared to be looking forward with gusto.

Barbour's first article for many years was the most complete and extensive on the subject and it was often referred to and his figures were republished several times. Bernard (1888) gives a review of Barbour's article and republishes one of his figures. Bateson (1894) refers to Barbour's article and republishes his four figures. Krause (1896) also reviews this article and copies one of Barbour's figures. Finally Newman (1923) republishes a line cut of the dorsal aspect of the same monster, giving Bateson (loc. cit.) credit for the description, as well as for the figure. Bateson, however, credits Barbour for both.

Girard (1891) published a rather crude drawing of a two-headed turtle, supposed by him to be *Chrysemys picta*, sent to him by a friend. The place of capture or observation is not stated. According to the drawing, the heads are of equal size and other parts are nearly normal. Duplicity in this animal appears to have been very similar to the one described and figured by Barbour (loc. cit.).

The Scientific American (1905) carries a brief article and an illustration reproduced from a photograph (author's name not given) of a double-headed tortoise said to be *Terrapine carolina*. This monster was taken near Mt. Vernon, Va. It had two heads nearly equal in size and was almost normal in other respects. This animal was alive when described and had gained growth and "measures some two by one and three-quarters inches, the shell being possibly a trifle larger than would ordinarily be the case." The heads did not act nor feed together and "appear otherwise independent."

Blatchley (1906) reports a double-headed turtle from Waterman, Fountain Co., Ind., which he knew only from a crude figure and description which appeared in the *Indianapolis News* of July 19, 1893. Blatchley judged the animal to be a lady turtle, *Chrysemys marginata*. The Indianapolis News, as quoted by Blatchley, stated that the animal had

nothing except the extra head to distinguish it from an ordinary small river turtle. It was thought, however, that the "back" appeared a little broader than usual. The animal was kept alive for more than a year when by accident it was drowned. The two heads in this specimen, as in other double-headed turtles described, behaved entirely independently.

Popular Science (1919, p. 59) publishes a crude figure of a double-headed turtle with the following notation, "This two-headed turtle lives in the Chicago Academy of Sciences." It is entirely impossible to recognize the species from the crude figure published. An inquiry concerning this monster, addressed to the Chicago Academy of Sciences, has brought no reply.

Glaesner (1924) describes three double turtle structures of *Chelonia mydas* from eggs collected on the Island Europa. The youngest of the three which is described and figured was in the gastrula stage and the other two were respectively in the 4 and 16 somite stages. This is the only article known to the writer in which duplicity in chelonia is described from the developing stages within the egg.

Under "Communications" in the Bulletin de la Societe d'Histoire Naturelle de l'Afrique du Nord (1925) a young 2-headed "terrestial tortoise" with 4 front feet, 2 hind feet, and one vent is described, the monster being double anteriorly but fused posteriorly. The place of collection is not given nor is the scientific name mentioned. Duplicity in this specimen apparently was further advanced than in any of the specimens previously described, and it had progressed further than in the specimen of diamond-back terrapin described in the present paper.

Light and Derickson (1926) describe a double headed turtle, *Chrysemys picta*, taken at Harpers, Lebanon County, Pa. This monster had two heads but was normal in so far that it had four legs and one tail. A radiograph of this specimen revealed the fact that two distinct vertebral columns extended backward to the pelvic region. Duplicity of the carapace appears to have corresponded quite closely to the specimen of diamond-back terrapin described in this paper. The authors state that the two heads of this monster, which lived about three months, sometimes acted in one accord but again they disagreed and the movements of the body were affected accordingly.

Derickson (1927) describes a double headed turtle, *Chrysemys picta*, from the same locality as the subject of the previous paper cited, and in large measure it constitutes a repetition of the previous article, no new facts being presented.

Townsend (1928) gives the most recently published account of duplic-

ity in chelonia that has come to the writer's attention. Figures of two different specimens are shown. Concerning one of the monsters Townsend reports that nothing is known, except that the photographs which are reproduced were made at Warsaw, New York, sometime prior to 1905, nor does he venture to name the species. The twins in this case are attached posteriorly, that is, the two heads are pointed in opposite directions. All the other double chelonia of which the present writer has seen descriptions or figures were attached laterally, that is, the heads were side by side. Townsend's double turtle had two nearly perfect carapaces united posteriorly. The photograph even shows marginal plates for both carapaces at the line of attachment. Duplicity in the plastron in this specimen, as in nearly all the others described, appears to be less complete than in the carapace.

Townsend (loc. cit.) also published a figure of a double-headed turtle taken in a Cuban stream, an account of which had previously appeared in *El Mundo*, a newspaper of Havana. This turtle had been identified as *Emys descussata*. Townsend's illustrations, reproduced from the Havana *El Mundo*, shows that the specimen had two heads of nearly equal size and duplicity probably was developed about as in Barbour's specimen mentioned on a preceding page.

It is evident from the published accounts reviewed, that duplicity in chelonia, occurs occasionally and that it is not so common that such monsters are not noticed. Only two types of twins appear to have been described, namely, those attached laterally, generally with two separate heads and with duplicity further developed in the anterior regions of the body than posteriorly and, second, the type with bodies united posteriorly with heads pointed in opposite directions. Of the last mentioned type only a single specimen has been reported. No notice of monsters in which duplicity had advanced further posteriorly than anteriorly, or even equally, has been found. The internal anatomy, as pointed out elsewhere, is not described in the literature cited.

VARIATIONS AND ABNORMALITIES IN DIAMOND-BACK TERRAPINS

A comparatively large variation in size in the young at hatching has been observed at Beaufort, but it is difficult to say at what size a young animal is abnormally small or abnormally large. A specimen only 14.0 mm. long (on the median line of the plastron) is at hand, and I have a record of one 31.5 mm. long. The average length, according to thousands of measurements of recenty hatched young, is close to 27 mm. The smallest individual at hand (14.0 mm.) is perfectly formed, both

internally and externally, so far as shown by a gross examination. Even the carapace and plastron are of about the usual firmness of a newly hatched terrapin. This small individual, although active for several weeks, died for reasons unknown. Deaths from no evident cause or causes also occur among animals of more nearly average size. It does not follow, therefore, that the small terrapin necessarily was weaker than many others of a larger size. The animal just described may be classed as abnormally small, as individuals of that size certainly are rare. Individuals 22 mm. in length are not unusual, however, and cannot be classed as abnormal in size. The variation above the average size (27 mm.), as already shown, is small and has many intermediates. Therefore, the largest recently hatched terrapin (31.5 mm.), of which we have a record, cannot properly be classed as abnormally large.

Some recently hatched young are proportionately much broader than others. However, the variations in this respect are rather gradual and generally do not constitute obvious abnormalities. It is understood, of course, that in adults the male is proportionately narrower than the female. It is not apparent that such a difference exists among the young, as the sexes are not distinguishable externally until considerable growth has been attained. The greatest average width of the carapace is close to one millimeter less than the average length of the plastron in recently hatched young and a variation of two or three or even four millimeters from these averages are to be expected. However, the brood of 1928 contained an obviously deformed individual which was close to a third broader than long. Furthermore, the carapace was rather depressed, whereas the plastron was so notably rounded, fore and aft, that the animal's feet scarcely reached the ground and it walked with some difficulty. This animal lived and gained growth and when about eight months old it was liberated.

Deformities appear to occur more frequently in the shells (carapace and plastron) than in any other part of the external structures. One deformity of the shells was mentioned in the preceding paragraph. Occasionally the scutes are incomplete, thus leaving an abnormally large part of the animal exposed. Probably a half dozen animals bearing this deformity have been noticed among the young. Adults with incomplete shells, too, are seen occasionally. In such animals it is difficult to determine, however, whether the deformity existed at birth or whether it was caused by injury or disease.

Bent or twisted scutes, or even bent and twisted shells occasionally are seen. There is at hand a live animal recently hatched in which, for

example, both the carapace and plastron are bent toward the right side posteriorly. The plates are of the normal number and, except for a slight twist along the median line, they seem to be regular in shape. The animal's feet do not "track," as the hind feet are further to the right than the front ones.

During the course of the experiments with diamond-back terrapin culture two animals have been hatched in which the eyes were undeveloped. One of these, hatched several years ago, was not seen by the writer. However, he has in hand a live individual, hatched in 1929, which is being retained for further observation. This animal appears to be normal in every other respect; it is of average size and vigorous and under artificial conditions it probably stands a fair chance to survive. Instead of having a normal bulging eye, this animal has slight depressions, where the almost empty orbit is situated. The orbits are overgrown with ordinary skin, bearing dark markings similar to those of the rest of the head. To the unaided eye the pits are scarcely visible. When examined under magnification it is seen, however, that the skin over the orbits is not directly continuous with that of the head, as a distinct demarcation exists. It is seen also that the skin of the orbit consists of three main sections which meet in the center where normally the pupil should be situated. While an opening cannot be seen even under fairly high magnification the writer is convinced that a slight aperture exists as the animal when handled exudes moisture at this point. This animal is gaining growth and apparently is in a healthy condition (March 10, 1930).

The skin over the orbits of this blind animal appears to be very sensitive and when touched it is drawn down, making the pits notably deeper than they are otherwise. A similar drawing in occurs when the cornea of a normal eye is touched, but not by merely touching the eye lids which do not appear to be very sensitive. It is evident, therefore, that although the eye ball apparently is missing in the abnormal animal, the muscles which normally control the eye, in part at least, are present.

ALBINISM

Only two albinos have been hatched to date. One of these appeared in the brood of 1913 and a second one in the brood of 1929. These animals lived only a few months. Although preserved, the specimen of the 1913 brood cannot be found at this time. However, it was a true albino, the body and shells being entirely destitute of pigment. With respect to size and external anatomy there were no obvious abnormalities.

The albino of the brood of 1929, had a plain white carapace and plastron, except for a yellowish tinge at the sutures of the scutes. The skin of the exposed parts was pinkish and the eyes were a bright red, the pupil being somewhat darker red than the rest of the eye. In size and external structure the animal was normal, except for a somewhat twisted tail. It appeared to be vigorous and to stand a fair chance to survive. However, it failed to take food and died at an age of about 5 months without having gained growth.

TWINNING

Only one double monster has been hatched during 20 years' experience with terrapin culture. Identical twins would be difficult to recognize and if such twins have been produced they were not noticed.

The double monster in hand was hatched in 1929, a year that appears to have brought forth far more abnormalities than any other one year during the course of the experiments. Reference will be made further on to the probable reasons for this increase in irregularities.

The double monster at hand, which lived only several days, has two well developed heads, the left one being of normal size, whereas the right one is considerably smaller; two tails of equal size, four normally developed legs and feet, placed as in a normal individual, the right ones being somewhat smaller than the left ones; and a fifth rudimentary leg, without a foot, situated between the heads. The carapace is essentially double and much broader, although scarcely as long as in a normal animal. It has two rows of vertebral scutes, each one consisting of the normal number (five) of plates and each bearing the characteristic median keel. The rows of lateral and marginal plates, situated respectively to the right and the left of each vertebral row, are crowded but rather regular in shape and they occur in the usual or normal numbers. The scutes between the two vertebral rows, however, are extremely crowded and in irregular series and all connected without indications of marginal plates. The development of the carapace in this region exceeded the expansion that took place in the rest of the animal, causing a high ridge or fold of irregular scutes between the two rows of vertebral plates.

The plastron, like the carapace, is much broader in proportion to its length, except posteriorly where it rather abruptly gets much narrower than in a normal animal. In addition to the usual number of plates, three additional ones are present, as two pairs of gular plates instead of one pair are developed, and between the two pairs of gular plates lies a

single broad abnormal plate. A single pair of each of the other plates, namely the pectoral, abdominal, preanal and anal is present as in a normal individual. Only the last (anal) pair meet on the median line, as in a normal specimen. The others are comparatively far apart, for they are no wider than these scutes are on a normal specimen, although the ventral surface, as already explained, is considerably broader. As a result, an area of relatively large size and roughly triangular in shape, is left unprotected by scutes and is covered with soft, white, glossy skin only, representing an abnormal umbilicus.

The principal parts of the external anatomy that are not double and do not show compete twins consist of the single pair of hind legs, the single pair of normally sutured anal plates, already described, and a single vent situated between the bases of the two tails.

The internal anatomy contains two hearts, two lungs, two livers, and two stomachs united with one intestine. Two spinal columns are present throughout; they become attached in the thoracic region but not fused and each one has a separate and distinct spinal cord.

The intestine, as already indicated, is single and it is much shorter than in a normal specimen. The urogenital system, too, is single and situated as in a normal individual. The "fifth leg," situated between the heads, has one complete and nearly normal pectoral girdle and two additional bones of a second one, resembling the procoracoid and the scapula. Although the shoulder girdle is partly double, the leg itself does not show the double character for it consists of only two short, very heavy, articulated bones, corresponding respectively to the humerus and to one of the bones of the forearm.

The presence of virtually a double central nervous system was shown by the behavior of the monster which was kept on the writer's desk for observation for some time before it died. The complete absence of coordination between the left and the right legs was evident, as they appeared never to become active at the same time. When the right legs took steps the left ones remained still and vice versa. The animal, therefore, walked in circles or more often in a zigzag line, the direction of its course depending upon the length of time one side was active and the other remained quiet.

THE CAUSE OF ABNORMALITIES

It has been held by Stockard (1921), Newman (1917 and 1923) and others that abnormalities may be caused or that twins may result by a temporary cessation or a radical retardation in the development of the

egg at a critical stage. The interference with the normal rate of development may be caused in nature by a variety of factors. The chief ones perhaps are sudden changes in temperature and an occasional deficiency of oxygen. Stockard (1921) was able to produce in the laboratory irregularities in *Fundulus* embryos by chilling the eggs during the cleavage stages and he secured similar results by reducing the supply of oxygen. Newman (1923), working with the eggs of the Pacific Coast starfish, *Patiria miniata*, secured irregularities in large numbers by methods largely similar to those used by Stockard.

The rather unusually large number of abnormal terrapins hatched in 1929 naturally caused the writer to look for the cause or causes. Since no change was made in the cultural methods used during several preceding years, the cause was sought in the conditions of the weather. Accordingly the records of temperature and precipitation, which are secured at the Fisheries Station, Beaufort, N. C., for the U. S. Weather Bureau, were studied. However, they reveal nothing which appears to be very significant. It is true that a decided drop in temperature took place early in June, near the beginning of the laying season (which extends from the latter part of May through June and July). That is, the maximum temperature on June 2 was 83° Fahrenheit and it dropped to 55° during the night of June 3, remaining rather low until June 6, when it again reached 83°. In the meantime one-fourth of an inch of rain fell and during the daylight hours the sky was clear so that no loss of sunshine took place. A somewhat similar drop in temperature and a light rainfall, however, occurred in June in 1921. That is, the temperature dropped from 80° Fahrenheit on June 5, to 56° during the night on June 7, returning to 80° on June 8. Precipitation amounted to three-hundredths of an inch, and the sky was clear during the daylight hours. The brood of this year (1921), however, contained few abnormal individuals. It is possible, of course, that when the drop came in 1921 that no eggs happened to be in an early critical cleavage state, whereas such eggs were present and affected at a critical time when the cold snap arrived in 1929. Then, too, the drop in 1929 was somewhat greater, amounting to 28° Fahrenheit, whereas in 1921 it amounted to 24° and, furthermore, in 1929 the cool snap lasted one day longer which may be of importance, as it naturally would take quite a while to cool the sand to a depth of 4 to 6 inches at which the eggs are deposited.

It has been suggested (Newman, 1923) that twinning in turtles occurs rarely, because the eggs have passed the critical stage when they are laid, for some evidence seems to be available indicating that the chelo-

nian embryo is a little further advanced at the time of laying than that of birds, for example, in which twinning appears to be more common. This is a matter which requires further study, and, if true, it seems to offer a reasonable explanation for the scarcity of chelonian twins.

CONCLUSION

Abnormalities of the embryo in the early stages of development have not been especially sought in the present studies. Ample evidence has been presented, however, to show that obvious irregularities in the anatomy of recently hatched diamond-back terrapins in the cultural work carried on at the Fisheries Biological Station, Beaufort, N. C., are not numerous. It has been shown also that twinning occurs extremely rarely. Furthermore, the literature contains comparatively few records of duplicity in chelonids.

The scarcity of abnormalities in recently hatched diamond-back terrapins at Beaufort, N. C., may be due to the rather even temperatures which prevail during the laying season and the incubation period. While fluctuations take place in temperature which may at times affect the normal development of certain embryos, as shown, the changes are by no means as great as they are farther north and particularly in the northern inland waters. Many irregularities (judging from the results obtained by various investigators and from the present investigation) apparently need not be expected under the circumstances in which the terrapin cultural work is being conducted at Beaufort, N. C.

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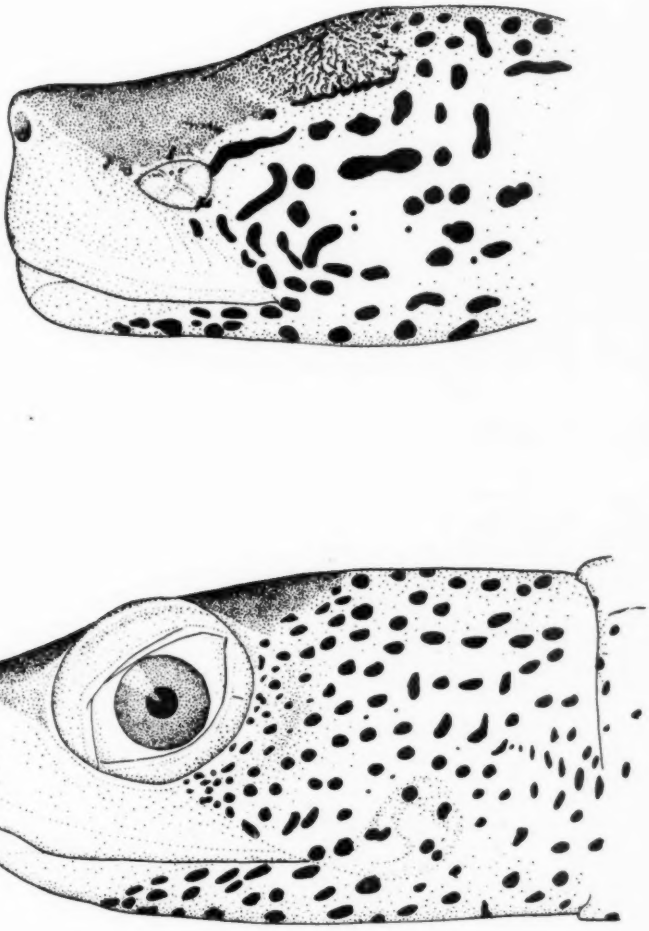
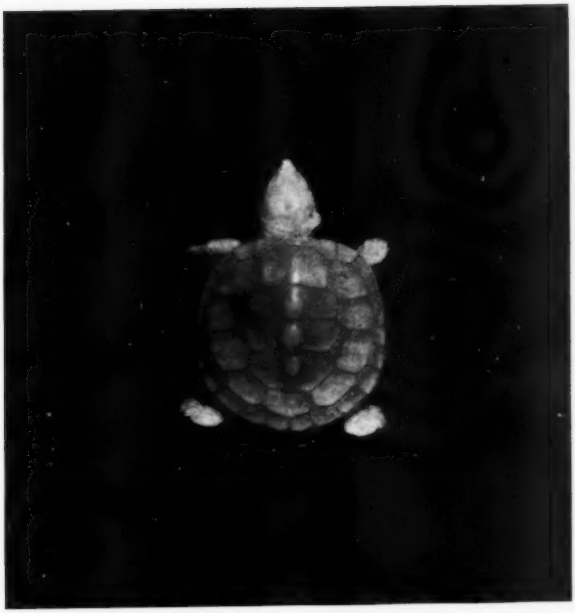
PLATE 1



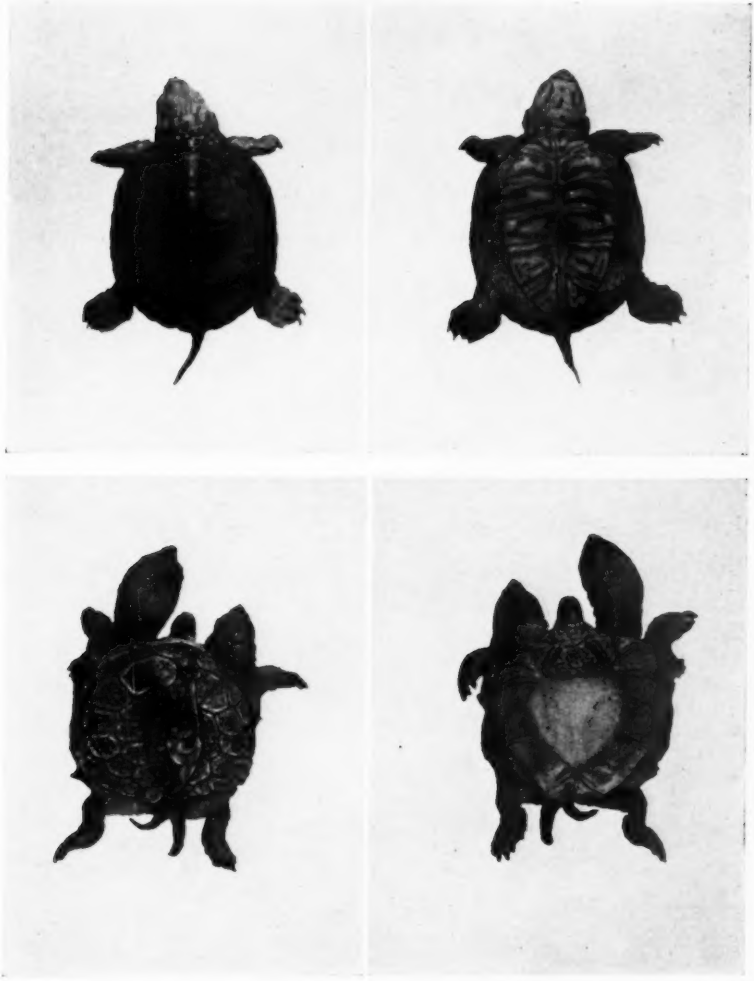
HEADS OF YOUNG DIAMOND-BACK TERRAPINS
Above: Animal without developed eye
Below: Animal with normal eye

PLATE 2



ALBINO TERRAPIN

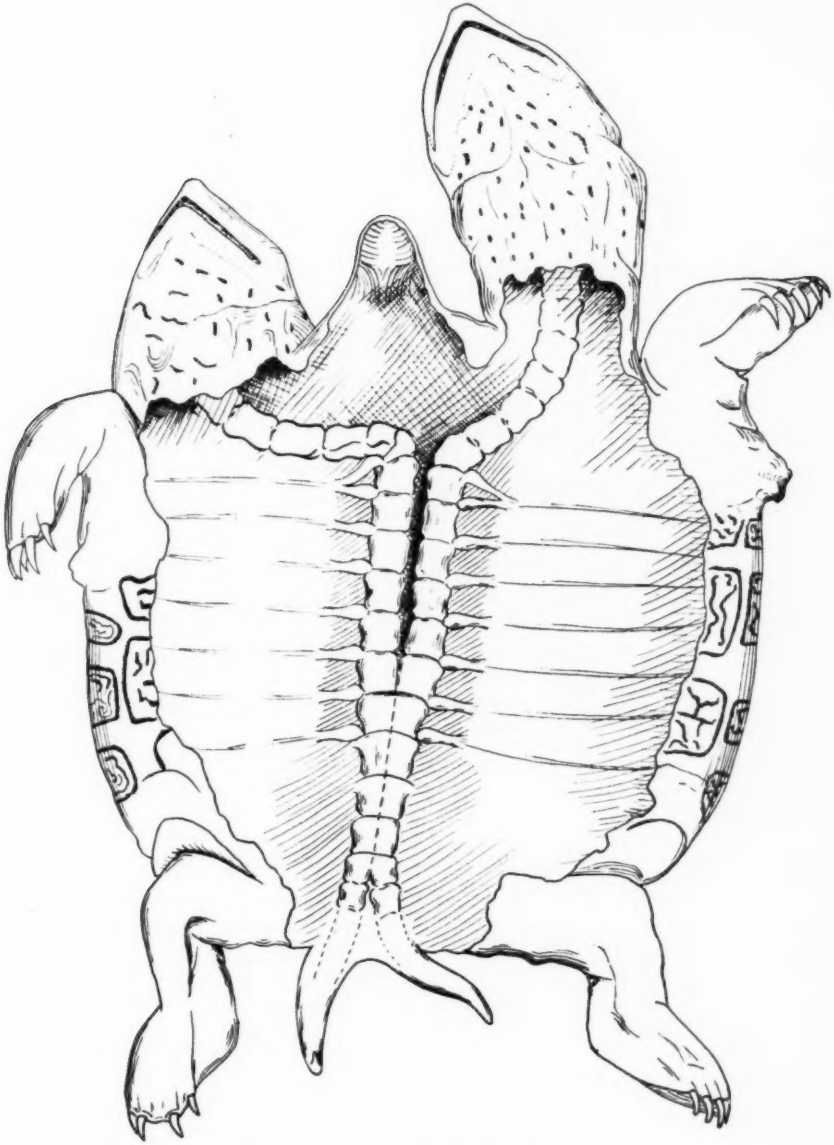
PLATE 3



Above: Normal diamond-back terrapin, shortly after hatching, about actual size. Left, dorsal view; right, ventral view.

Below: Double diamond-back terrapin, about actual size. Left, dorsal view; right, ventral view.

PLATE 4



DOUBLE DIAMOND-BACK TERRAPIN MONSTER, SHOWN ON PL. 3, WITH PLASTRON AND INTERNAL ORGANS REMOVED

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THE DETERMINATION OF SMALL AMOUNTS OF HYDROGEN SULFIDE[1]

By W. V. Harshman, D. A. McPherson, and F. H. Edmister

During the past fifty years a great many methods for determination of sulfur in the sulfides have been proposed—volumetric, gasometric, gravimetric, and colorimetric.

With a view of adapting one of these methods to the determination of small amounts of hydrogen sulfide such as is produced by certain types of bacteria, this investigation was made. The procedure where the hydrogen sulfide is aspirated through standard iodine, thence through thiosulfate solutions, was used after various other methods were proved unsatisfactory for our purposes.

The attempt to add the iodine directly to the hydrogen sulfide solution acidified with hydrochloric acid gave varying results. This again confirms the work of Washburn (1) and others.

An attempt was made to use the method worked out by Fellers, Sostrum and Clark (2). Various amounts of air were drawn through the solutions: 5, 10, 15, and 20 cu. ft. in an effort to secure a correction factor. It was found, however, that in some instances a small volume of air caused a greater iodine loss than a large volume.

For the following titrations c. p. Baker chemicals were used. Both the iodine and thiosulfate were recrystallized according to Treadwell (3). In making the iodine solution the amount of KI used was double that generally specified in order to prevent the crystallizing of the iodine upon the walls of the burette. The iodine solution was preserved in black bottles, and the thiosulfate solution kept in an amber bottle and protected from the air by a layer of naphtha. The outlet for the thio solution was a rubber tube closed by a glass plug. This arrangement prevented the drying out and crystallizing of any thiosulfate which happens when a pinch clamp is used.

The starch indicator solution was made in the usual manner by dissolving the starch in hot water and adding a preservative.

[1] From a thesis submitted to the Faculty of the Chemistry Department by W. V. Harshman in partial fulfillment of the requirements for a Master of Science degree.

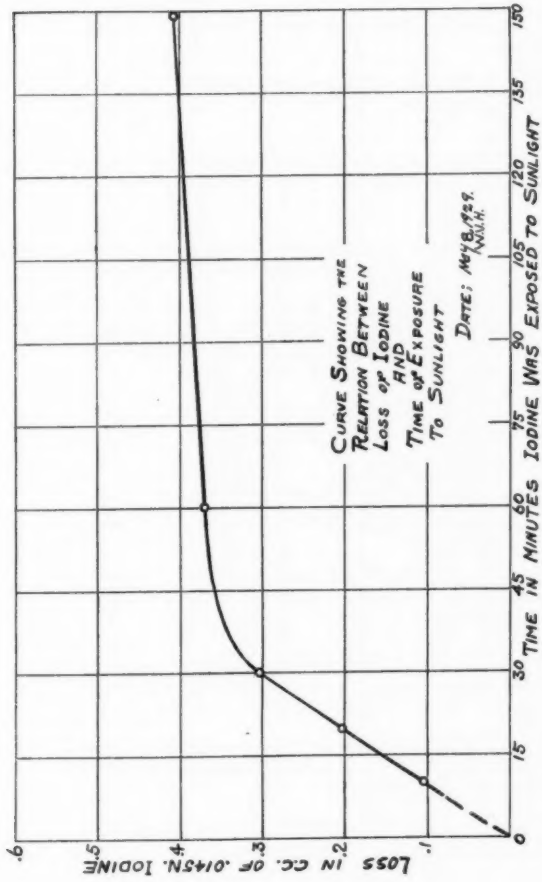

FIG. 1. CURVE SHOWING THE RELATION BETWEEN LOSS OF IODINE AND TIME OF EXPOSURE TO SUNLIGHT

Figure 1 shows the effect of exposing a bottle of the iodine solution to sunlight for two and a half hours, and needs no explanation.

To determine the effect of "aging" on these solutions, the ratio of the volumes required to obtain an end point was determined from time to time over a period of three months. Variations in the thio solution was marked up to the fourth day then gradually decreased up to the seventh day after which it remained constant. The iodine value very quickly became constant.

TABLE I

BURETTES NOT WASHED

Series 1

THIOSULFATE NO. 2 TITRATED AGAINST IODINE NO. 3			IODINE NO. 3 TITRATED AGAINST THIOSULFATE NO. 2		
	Factor			Factor	
9.79 cc.	0.899	8.805 cc.	8.51 cc.	0.891	9.55 cc.
9.55 cc.	0.900	8.60 cc.	8.80 cc.	0.893	9.77 cc.
9.79 cc.	0.901	8.82 cc.	8.78 cc.	0.894	9.80 cc.
9.56 cc.	0.904	8.64 cc.	8.87 cc.	0.895	9.90 cc.
9.51 cc.	0.905	8.61 cc.	8.78 cc.	0.896	9.80 cc.
9.60 cc.	0.906	8.72 cc.	8.28 cc.	0.898	9.21 cc.
			Series 2		
9.45 cc.	0.898	8.49 cc.	8.50 cc.	0.890	9.55 cc.
9.79 cc.	0.900	8.99 cc.	8.52 cc.	0.892	9.55 cc.
9.79 cc.	0.901	8.82 cc.	8.51 cc.	0.891	9.55 cc.
9.56 cc.	0.904	8.64 cc.	8.75 cc.	0.893	9.81 cc.
9.51 cc.	0.905	8.61 cc.	8.55 cc.	0.895	9.55 cc.
9.62 cc.	0.906	8.71 cc.	8.61 cc.	0.896	9.60 cc.

Series 1 and Series 2 used simply to designate different solutions.

No measurable loss was detected in the iodine solution by aspirating carbon dioxide through it, but there was a slight loss when it was bubbled through the thio solution. This is similar to the results obtained by Kolthoff (4).

EXPLANATION OF TABLES. IODINE SOLUTIONS 100/N, AND 10/N

Table I, series 1, shows results obtained when titrations were continuously carried on. In all cases as will be noted a continuously increasing amount of iodine was necessary to titrate the same amount of thiosulfate solution.

TABLE II

BURETTES WASHED AFTER EACH TITRATION

Series 1

THIOSULFATE NO. 3 TITRATED AGAINST IODINE NO. 3			IODINE NO. 3 TITRATED AGAINST THIOSULFATE NO. 3		
	Factor			Factor	
9.30 cc.	1.072	9.97 cc.	9.70 cc.	1.066	9.10 cc.
9.06 cc.	1.072	9.71 cc.	9.80 cc.	1.065	9.20 cc.
9.02 cc.	1.070	9.65 cc.	9.67 cc.	1.068	9.05 cc.
8.90 cc.	1.073	9.55 cc.	9.75 cc.	1.066	9.14 cc.
8.93 cc.	1.071	9.53 cc.	9.82 cc.	1.067	9.20 cc.
8.92 cc.	1.070	9.53 cc.	9.84 cc.	1.068	9.21 cc.
9.02 cc.	1.074	9.68 cc.	9.67 cc.	1.068	9.05 cc.
9.10 cc.	1.071	9.75 cc.			

Series 2

THIOSULFATE NO. 4 (0.01 N) TITRATED AGAINST IODINE NO. 4 (0.01 N)			IODINE NO. 4 (0.01 N) TITRATED AGAINST THIOSULFATE NO. 4 (0.01 N)		
	Factor			Factor	
9.40 cc.	1.030	9.56 cc.	9.48 cc.	1.007	9.41 cc.
9.34 cc.	1.029	9.62 cc.	9.30 cc.	1.001	9.25 cc.
9.32 cc.	1.035	9.65 cc.	9.25 cc.	1.008	9.17 cc.
9.62 cc.	1.031	9.91 cc.	9.51 cc.	*1.031	9.22 cc.
9.13 cc.	1.028	9.39 cc.	9.25 cc.	1.019	9.15 cc.
8.44 cc.	*1.090	9.20 cc.			

* Note: Iodine burette was not cleaned following previous titration. The variation in the factors is attributed to difficulty encountered in reading end-points.

Series 3

THIOSULFATE NO. 4 TITRATED AGAINST IODINE NO. 4			IODINE NO. 4 TITRATED AGAINST THIOSULFATE NO. 4		
	Factor			Factor	
7.92 cc.	1.015	8.04 cc. + 4 gm. KI	9.06 cc.	1.000	9.07 cc. + 2 gm. KI
8.60 cc.	1.008	8.67 cc. + 2 gm. KI	9.01 cc.	1.000	9.01 cc. + 2 gm. KI
8.92 cc.	1.011	9.02 cc. + 2 gm. KI	9.10 cc.	1.001	9.09 cc. + 2 gm. KI
9.31 cc.	1.009	9.39 cc. + 2 gm. KI	9.27 cc.	1.000	9.27 cc. + 2 gm. KI
8.98 cc.	1.012	9.09 cc. + 2 gm. KI	9.43 cc.	1.002	9.45 cc. + 2 gm. KI

Note: As shown by data, here the addition of a small amount of KI enables one to get more constant factors. It is to be noted that the starch-iodide blue does not disappear and return again under these conditions.

Table II shows the contrast between titrations when the burettes were not cleaned after each titration; and when they were. In this table under series 3 additional KI was used. The results indicate the value of a slight excess of KI in the iodine solution.

Table III is a summary of a number of runs and titrations showing the effect of aspirating air through the two solutions. In all cases there was an appreciable loss of iodine but no relation between this loss and

TABLE III

ASPIRATION OF AIR THROUGH IODINE AND THIOSULFATE SOLUTIONS

SERIES	VOLUME OF I_2 3 RUN INTO A BEFORE ASPIRATION	VOLUME OF $Na_2S_2O_3$ 2 RUN INTO B AND C BEFORE ASPIRATION	VOLUME OF AIR DRAWN THROUGH	VOLUME OF I_2 IN TITRATION AFTER ASPIRATION	VOLUME OF $Na_2S_2O_3$ IN TITRATION AFTER ASPIRATION	LOSS OF IODINE
1	7.00 cc.	10.00 cc.	7.5 ft.^{3}	8.415 cc.	6.70 cc.	0.51 cc.
2	7.05 cc.	10.00 cc.	5.0 ft.^{3}	8.44 cc.	6.80 cc.	0.45 cc.
3	7.00 cc.	10.00 cc.	4.0 ft.^{3}	7.55 cc.	5.64 cc.	0.54 cc.
4	7.00 cc.	10.00 cc.	10.0 ft.^{3}	7.27 cc.	5.73 cc.	0.27 cc.
5	7.00 cc.	10.00 cc.	5.0 ft.^{3}	7.78 cc.	6.35 cc.	0.32 cc.

TABLE IV

ASPIRATION OF NITROGEN THROUGH IODINE AND THIOSULFATE SOLUTIONS

SERIES	VOLUME OF I_2 3 RUN INTO A BEFORE ASPIRATION	VOLUME OF $Na_2S_2O_3$ 3 RUN INTO B AND C BEFORE ASPIRATION	VOLUME OF N_2 DRAWN THROUGH	VOLUME OF I_2 USED IN TITRATION	VOLUME OF $Na_2S_2O_3$ USED IN TITRATION	LOSS OF IODINE
1	7.00 cc.	9.00 cc.	3.5 ft.^{3}	8.67 cc.	5.57 cc.	0.06 cc.
2	7.00 cc.	9.06 cc.	5.0 ft.^{3}	8.59 cc.	5.45 cc.	0.09 cc.
3	7.90 cc.	9.00 cc.	5.0 ft.^{3}	10.05 cc.	7.64 cc.	0.05 cc.
4	7.00 cc.	9.00 cc.	10.0 ft.^{3}	8.47 cc.	5.32 cc.	0.15 cc.
5	7.00 cc.	9.00 cc.	10.0 ft.^{3}	7.95 cc.	4.85 cc.	0.12 cc.

the amount of air drawn through. Since the results were so inconsistent, the procedure was modified by substituting nitrogen for the air. The results are given in table IV, which clearly shows that the loss of iodine, while appreciable, is much less and more nearly constant than when air is used.

It was found that when KI was added to both the iodine and the thio solutions before aspirating different results were obtained than when it was added after aspirating, or omitted altogether. The data are given

TABLE V

ASPIRATION OF NITROGEN THROUGH 0.01 N IODINE AND 0.01 N THIOSULFATE

SERIES	VOLUME OF I_2 4 RUN INTO A BEFORE ASPIRATION	VOLUME OF $Na_2S_2O_3$ 4 RUN INTO B AND C BEFORE ASPIRATION	VOLUME OF N_2	VOLUME OF I_2 USED IN TITRATION	VOLUME OF $Na_2S_2O_3$ USED IN TITRATION	LOSS OF IODINE
1	8.00 cc. + 4 gm. KI	9.00 cc. + 0 gm. KI	5.0 ft.^{3}	9.40 cc.	8.20 cc.	0.03 cc.
2	8.00 cc. + 4 gm. KI	9.00 cc. + 4 gm. KI	5.0 ft.^{3}	9.35 cc.	8.22 cc.	0.00 cc.
3	8.00 cc. + 4 gm. KI	9.00 cc. + 4 gm. KI	5.0 ft.^{3}	9.33 cc.	8.26 cc.	0.00 cc.
4	8.01 cc. + 4 gm. KI	9.01 cc. + 4 gm. KI	5.0 ft.^{3}	9.90 cc.	8.76 cc.	0.00 cc.
5	8.00 cc. + 2 gm. KI	9.00 cc. + 2 gm. KI	5.0 ft.^{3}	9.15 cc.	8.05 cc.	0.00 cc.
6	8.00 cc. + 2 gm. KI	8.99 cc. + 2 gm. KI	10.0 ft.^{3}	9.02 cc.	7.95 cc.	0.00 cc.
7	8.50 cc. + 0 gm. KI	9.00 cc. + 0 gm. KI	5.0 ft.^{3}	7.38 cc. + 2 gm. KI	6.15 cc. + 2 gm. KI	0.08 cc.
8	8.00 cc. + 2 gm. KI	9.00 cc. + 2 gm. KI	5.0 ft.^{3}	9.42 cc.	8.40 cc.	0.02 cc.
9	8.00 cc. + 2 gm. KI	9.01 cc. + 2 gm. KI	5.0 ft.^{3}	9.01 cc.	7.93 cc.	0.00 cc.
10	8.00 cc. + 2 gm. KI	9.00 cc. + 0 gm. KI	5.0 ft.^{3}	9.34 cc.	8.11 cc. + 2 gm. KI	0.06 cc.

TABLE VI

ASPIRATION OF AIR THROUGH IODINE AND THIOSULFATE SOLUTIONS, 4 RESPECTIVELY

SERIES	VOLUME OF I_2 4 RUN INTO A BEFORE ASPIRATION	VOLUME OF $Na_2S_2O_3$ 4 RUN INTO B AND C BEFORE ASPIRATION	VOLUME OF AIR	VOLUME OF I_2 USED IN TITRATION	VOLUME OF $Na_2S_2O_3$ USED IN TITRATION	LOSS OF IODINE
1	8.00 cc. + 2 gm. KI	9.00 cc. + 0 gm. KI	5.0 ft.^{3}	9.34 cc.	8.11 cc. + 2 gm. KI	0.06 cc.
2	8.00 cc. + 2 gm. KI	9.00 cc. + 2 gm. KI	5.5 ft.^{3}	9.62 cc.	8.19 cc.	0.26 cc.
3	8.00 cc. + 2 gm. KI	9.00 cc. + 2 gm. KI	10.0 ft.^{3}	9.22 cc.	7.95 cc.	0.10 cc.

in table V. Four grams of KI seemed to have the same effect as two grams.

Table VI gives the results of three sets of titrations where the KI was added before titration and then air was aspirated through the solutions. The results are again unsatisfactory.

Table VII shows results similar to those obtained by Anderson (5) under analogous conditions. A solution of K_2S was run in beneath the surface of an iodine solution made slightly acid with HCl. The results of the titrations are in decided disagreement. It is to be observed for example, that when 20 cc. of the K_2S solution was used the amount of iodine was not double that used when 10 cc. was titrated.

TABLE VII

DETERMINATION OF S^- IN K_2S

SAMPLE	VOLUME OF SAMPLE	IODINE USED (0.0145 N)	PER CENT S
1	10 cc.	1.87 cc.	
2	10 cc.	1.97 cc.	17.89
3	10 cc.	1.92 cc.	
4	10 cc.	1.52 cc.	23.23
5	10 cc.	1.97 cc.	
6	20 cc.	3.53 cc.	
7	20 cc.	3.50 cc.	20.6

Again checking the findings of Brunck (6) it was observed that a very slightly smaller volume was required to obtain an end point when the iodine was run into the thio solution than the reverse. It was also found that it is not advisable to accept an end point that has been obtained by approaching from the thiosulfate side, but that a slight excess of iodine should be added, then titrated back with the thio until the color is obtained.

By making the above modifications it has been possible to determine the hydrogen sulfide (S) content of very dilute solutions to 0.11 per cent error. In such solutions (0.006–0.008 gm. K_2S) a small error in titration produces a large percentage error in results. Probably the most common error is in matching the color of the successive titrations, since the blue is more or less transient.

SUMMARY

No new method is proposed, but certain modifications of existing methods are advocated.

The results obtained in titrating the hydrogen sulfide produced by microorganisms were not very satisfactory, quantitatively, and it is doubtful if there is at present a method sensitive enough to measure accurately the very minute amounts produced by them. Results obtained during the course of these experiments gave a variation of from 0.0001 to 0.0002 gm. of iodine used. While the actual difference is extremely small it seems unwise to publish these results since the method proposed could not be relied upon to differentiate between strains of an organism.

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WINTER ROOT DEVELOPMENT OF LIGUSTRUM VULGARE

By Frankie Jo Mann

Introduction

Plates 5, 6

In the section around Greensboro, North Carolina, the nurserymen advocate planting shrubs during the fall and spring. It is the aim of this work to find out when root growth takes place in shrubs transplanted in the fall and the spring as compared with those not transplanted. Little work has been done in the study of winter development of roots and most of this has been with cuttings.

History

Carlson, in her experiments with rose cuttings, found that temperature had a decided effect on the development of roots and rooting behavior. Zimmerman, in his investigations with cuttings, found that leaves played an important part in the rooting. The cuttings that had one leaf rooted in two weeks, and those without leaves did not root at all. Also, as autumn approaches there is a time when leaves can be dispensed with. His conclusion was that the larger the number of leaves that can be kept in good condition, the better the root growth will be. In their experiments, Hitchcook and Zimmerman discovered that cuttings taken in August produce normal fibrous roots. Cuttings taken in October often do not form roots but use the basal ends of the stems for storage. In the September cuttings a few fibrous roots were produced, but there was a tendency to produce storage roots. Rogers experimented with weeds and found that shoots continued to develop buds on horizontal roots of Canada Thistle from the middle of September to the middle of November. No new shoots were formed upon roots taken from cold, but incompletely frozen, soil. In January the latent buds were increased considerably over those samples taken three weeks previously. By the middle of January new roots were found on old roots and on the newer roots of the previous fall which greatly exceeded those in January. By March 15th, the soil was not frozen and development of the whole root system became rapid. Crider found that certain

plants which had been thought to be dormant during the winter, made continuous growth. This is true both of deciduous and evergreen species, of cultivated and wild. The rate of root growth per day of species observed, varied from 9 mm. in November (Maximum) to 0.5 mm. in February. There appeared to be no direct or close correlation between daily growth and soil temperature, but growth was affected by seasonal temperature of soil. Other plants under the same conditions made no root growth whatsoever.

METHODS

Plants were dug at different periods beginning October 8, 1929, and continuing until March 25, 1930. The *Ligustrum vulgare* plants were dug, pruned, replanted, and later dug again for observations. In most of the cases about two-thirds of the shoot system and from one half to two-thirds of the root system were pruned away. Plants that had not been disturbed were studied for comparison with those that had been transplanted.

RESULTS

The first group, numbered 5, 6, 7, 8, of *Ligustrum vulgare* was dug on October 8, 1929. No care was exercised to protect or get the full length of the roots. The longest roots wee 30 inches long. When these plants were replanted, all of the roots were cut to 3½ inches to 4 inches which included most of the branch roots. Number 6 was dug again one month later. There were 13 or 14 new 3-inch roots, 6 to 8 that were 4 to 5 inches long and 3 to 5 that were 2 to 3 inches. The longest of the new roots were pruned. Plate 5 shows two views of this plant. The new roots can be seen as the white smooth part. The ruler indicates the length. Number 5 was dug again November 15, 1929, and one root had 8 to 10 new roots that were 1½ inches long, and a group of ⅞-inch ones, also a group of ¾-inch ones. Number 7 was dug the second time four months after transplanting. This plant had 7 to 9 new roots that were 4 to 5 inches long and as many that were 3 to 4 inches, most of them having a few branch roots. There were 10 to 14 new 1 to 2 inch roots. Number 8 was dug again on March 19 and there were several new tips and small new roots.

The next group, numbered 12 to 29, was dug January 2, 1930. Their roots were pruned to 4 to 5 inches. There was little recent growth indicated. No. 13 was dug a month later. Plate 6 (top figure) shows that practically no new roots were present. There was one good sized

new root coming from the main root that was 2½ inches long, and 5 to 9 small new ones 1 to 2 inches in length. Number 14 was dug at the same time. There were 4 to 5 new roots from the main root, from 2 to 4 inches each with 1 to 2 branch roots. There was one 2-inch root and one 1¼-inch one, but no new roots where the old ones were pruned. Nos. 15 and 16 were dug the second time on February 25. Neither showed any new growth. Plate 6 (bottom figure) shows No. 15 and no new growth is seen. The buds were beginning to swell and turn green on the shoot. Nos. 17 and 18 were dug March 4, two months after the first planting, but there was no new growth. The very tip of a new root which was present when first dug showed signs of recent growth. On March 19, No. 19 showed no new roots and practically no swelling of the buds was apparent. On the same date No. 12 had only 2 tips beginning to grow and no other new growth was observed. On March 25, the same plant had one small branch with 5 new ⅛ to ¼ inch roots. The tips of the roots that grew last fall showed signs of recent growth. No. 29 had quite a few new roots ¼ to ½ inches long when observed at this time.

The third group, numbered 37 to 49, was pruned and transplanted on March 14. No. 38 showed scarcely any growth on March 25. Only 2 tips were observed to be growing.

Plants that had not previously been disturbed and that had a few small leaves, showed recent root development on March 25. Another one that did not have so many leaves had also begun growth.

SUMMARY

From these results it is evident that more rapid root growth take place when the plants are transplanted in the fall and that the roots do have a period of rest during the winter; as is shown by comparison of No. 6, transplanted in the fall and dug again one month later which showed profuse new growth, with No. 13, transplanted in January and observed after the same length of time which shows no new growth. No. 7 was transplanted as No. 6 and after four months there was little more growth than occurred in a month in the fall as shown by No. 6. Of the different plants that were dug from January 2 to March 25, none showed any new growth, but after March 25 growth was rapid. This indicates that the roots of *Ligustrum vulgare* have a dormant period from sometime previous to January 2 to March 25. The results also show that those plants transplanted in the fall begin growth earlier than those dug in winter, early spring, or not dug at all. This is shown by the

fact that number 8, one of the first group, showed growth as early as March 19. The next, in order of development of roots, were those dug in January shown by No. 29 which were growing by March 25 more abundantly than plants that had not been previously disturbed. While plants transplanted in the early spring (March 14) had just begun growth on this date.

These results indicate that those plants which were transplanted in October developed more and longer roots in the fall and began growth earlier in the spring than those transplanted in winter, early spring, or the ones which had not previously been disturbed. The transplanting and pruning of *Ligustrum vulgare* seems to shorten the rest period of the root system and thus stimulate a more abundant root growth.

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EXPLANATION OF PLATES 5 AND 6

PLATE 5

Above: A bottom view of No. 6. The horizontal lines show the origin of the new roots and thus show the full length of them.

Below: A view of No. 6 which was dug the second time in November, one month after transplanting. The new roots may be seen as the smooth white part.

PLATE 6

Above: A view of No. 13 taken in February one month after transplanting. There is no new growth seen. The pencil points to an old root that had been pruned and no new roots are seen.

Below: A view of No. 15 dug on February 25 after transplanting in January. No new growth is seen.

PLATE 5

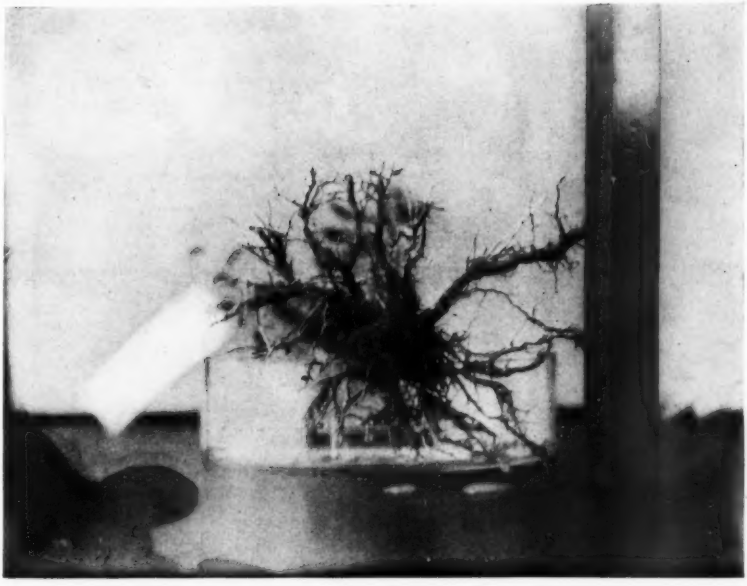
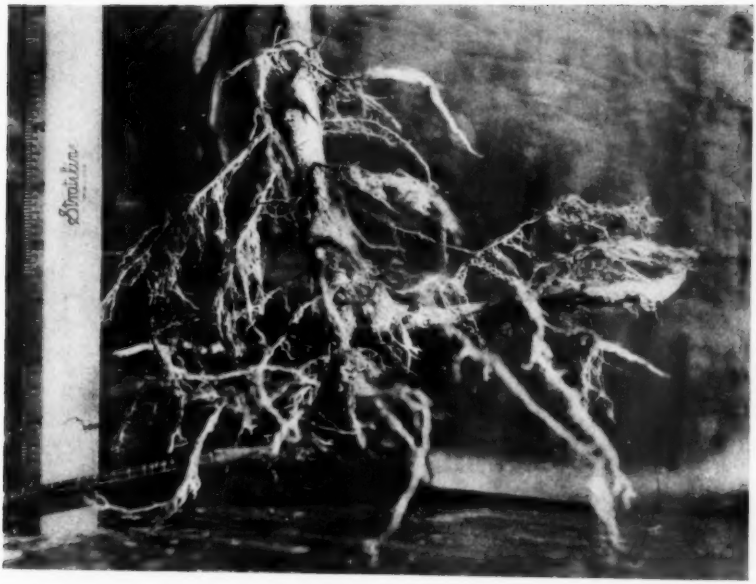


PLATE 6



THE JONESBORO FAULT SCARP WEST OF CARY, N. C.

By E. F. Goldston and Jasper L. Stuckey

The Triassic formations of North Carolina are commonly divided into three areas, the Deep River Area, the Dan River Area, and the Wadesboro Area. All three of these areas are of interest and have received more or less attention in the literature, but the Deep River Area has been studied in more detail because of its coal field. This area as commonly recognized begins near Oxford, Granville County, and ends a short distance west of Drowning Creek in Richmond and Montgomery Counties.

In the present investigation the writers have been interested in the structure of a small part of the Deep River Area just west of Cary.

Kerr in his geology of North Carolina indicated that the eastern edge of the Deep River Area was a normal erosional surface. In his study of "The Newark System," Bull. 85, U. S. Geol. Survey, I. C. Russell stated that on the east side of the area near Cary notches were observed in its outline which probably indicated faulting.

Campbell and Kimball in their study of "The Deep River Coal Field of North Carolina," Bull. 33, N. C. Geological and Economic Survey, described and mapped the Jonesboro fault as the most interesting structural feature of the Deep River Area. This fault, which marks the eastern boundary of the Deep River Triassic Area, was mapped by them from Jonesboro, the type locality, to a point just south of Carthage, where it is covered by the later sands of the sand hill region. To the northeast of Jonesboro they traced the fault to a point three miles east of Corinth, Chatham County, and beyond the limit of their map. They described it as a normal fault with the crystalline rocks on the southeast forming the foot wall and the Triassic rocks on the northwest side forming the hanging wall.

In the fall of 1927 the writers observed a prominent fault zone in a cut on the Southern Railway two miles west of Cary. At this point a fault shear zone some 50 feet wide marks the contact between the Triassic and the Algonkin rocks, which are crystalline schists.

Early in the spring of 1929 the writers made a detail study of a small area west of Cary, along the contact between the Triassic and the

crystalline schists. In this investigation it was comparatively easy to trace a prominent fault both to the northeast and southwest of the exposure in the railroad cut. While the fault has not been traced to Corinth, where Campbell and Kimball left off in their map, there seems little doubt of its being a continuation of the Jonesboro fault.

North of State Highway 10, at a point opposite the fault exposure in the railroad cut, a prominent notch may be seen in the topography which is doubtless the scarp of this fault. The most interesting locality, however, is to be found about one quarter of a mile south of the railroad where a small stream, which rises near Cary, flows from the crystalline rocks onto the Triassic formation and follows along the fault line. The Triassic rocks being soft and also broken due to faulting have been eroded away. The stream has formed a broad valley which grades gradually upward on the northwest to the normal topographic level. On the southeast side the crystalline rocks stand out as a definite line of hills which rise to an elevation of some 50 feet above the flood plain.

In the railroad cut the fault strikes approximately N. 65° E. To the southwest it swings more nearly to a N. 80° E. Near the fault the Triassic rocks are coarse conglomerate made up largely of rounded boulders and pebbles of volcanic materials, while away from the fault they become normal sandstone and shale. They dip at an angle of 5° to 10° to the northwest. The crystalline schists are volcanic rocks of Algonkin age. Faulting doubtless took place in Triassic time and the coarse materials which now form the conglomerate were carried from the southeast by small streams flowing over a steep grade. The present fault scarp is due to erosion by a small tributary of Crabtree Creek.

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A PARTIAL CHECK LIST OF THE FERNS FOUND IN THE MOUNTAIN PARK AND ROARING GAP REGION

By Earl H. Hall

In teaching and lecturing to teachers and prospective teachers I have received much convincing testimony that they are eager to familiarize themselves with the inhabitants of field and woods. They have come to feel that this familiarity affords a lasting joy and is a sign of culture. It has always been my experience that a world of delight opens before us when we are admitted into some sort of intimacy with companions other than humans.

It seems strange that the abundance of ferns everywhere has not aroused more curiosity as to their names, haunts, and habits. This desire to study ferns can be further supplemented by the fact that there is a small number of species in such an abundance of material. With this fact in view one may become familiar with a large portion of the ferns from any community in a single summer. It is still more surprising that such little effort is put forth in a community where all the common and many of the rare ferns are to be had for a little effort.

The ferns which comprise this list were collected last summer between July 25 and August 28 (1929) while teaching at Mt. Park Summer School, which was conducted by N. C. C. W. The collections were made on short excursions to interesting places of the vicinity where they were partially identified. This identification has been rechecked and revised by Miss Gertrude Grimsley whose interest and enthusiasm led to the collecting.

For purpose of classifying, these ferns were arranged in six groups according to their manner of fruiting.

Group I

Sterile and fertile fronds totally unlike; fertile fronds not leaf-like in appearance

1. Sensitive Fern
   Onoclea sensilibis
2. Cinnamon Fern
   Osmunda cinnamomea

GROUP II

Fertile fronds partially leaf-like, the fertile portion unlike the rest of the frond

3. ROYAL FERN
   Osmunda regalis
4. INTERRUPTED FERN
   Osmunda Claytoniana
5. RATTLESNAKE FERN
   Botrychium virginianum
6. CLIMBING FERN
   Lygodium palmatum
7. TERNATE GRAPE FERN
   Botrychium dissectum

GROUP III

Fertile fronds uniformly somewhat leaf-like in appearance, yet differing noticeably from sterile fronds

8. CHRISTMAS FERN
   Aspidium acrostichoides
9. NARROW-LEAVED SPLEENWORT
   Asplenium angustifolium

GROUP IV

Fertile and sterile fronds leaf-like and similar; sporangia on or beneath a reflexed portion of the margin

10. BRAKE FERN
    Pteridium aquilina
11. MAIDENHAIR FERN
    Adiantum pedatum
12. HAY-SCENTED FERN
    Dicksonia pilosiuscula

GROUP V

Fertile and sterile fronds leaf-like and similar; sporangia in linear or oblong fruit dots

13. LADY FERN
    Asplenium Filix-foemina
14. SILVER SPLEENWORT
    Asplenium thelypteroides
15. RUE SPLEENWORT
    Asplenium Ruta-muraria
16. MOUNTAIN SPLEENWORT
    Asplenium montanum
17. MAIDENHAIR SPLEENWORT
    Asplenium trichomanes
18. EBONY SPLEENWORT
    Asplenium platyneuron

19. GREEN SPLEENWORT
Asplenium viride
20. WALKING FERN
Camptosorus rhizophyllus

GROUP VI

Fertile and sterile fronds leaf-like and usually similar; fruit dots round

21. NEW YORK FERN
Aspidium Noveboracense
22. SPINULOSE WOOD FERN
Aspidium spinulosum var. *intermedia*
23. CRESTED SHIELD FERN
Aspidium cristatum
24. EVERGREEN WOOD FERN
Aspidium marginale
25. COMMON POLYPOD
Polypodium vulgare
26. GRAY POLYPOD
Polypodium polypodioides
27. LONG BEECH FERN
Phegopteris polypodioides
28. BROAD BEECH FERN
Phegopteris hexagonoptera
29. BLUNT-LOBED WOODSIA
Woodsia obtusa

This list of ferns, I hope, may serve to awaken enthusiasm in a pursuit which is so full of a peculiar fascination. Almost any one who has studied our native ferns will recall the thrill when a rare fern is unexpectedly located. Moreover the ferns may act as an agency to make companions more companionable by means of a common interest in their names, haunts, and habits.

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SOME OBSERVATIONS ON TILIA (BASSWOOD) SEEDS

By GERTRUDE GRIMSLEY

Tilia seeds are known to have a natural dormant period of eight to twelve months. The cause of this dormancy is not known, but it is thought to be due to some conditions existing within the seed itself since the seed coats appear not to hinder the entrance or exit of water or gases to and from the embryo and endosperm. For many years botanists, foresters, and nurserymen have worked with this problem of dormancy to try to find some adequate method for breaking the rest period and hastening and insuring germination, but until now no adequate method has been found for breaking this dormancy until the seeds have remained in the dormant state for at least eight months.

The percentage of germination of basswood seeds is low in both northern and southern regions. Even though the seeds produced are sound and plump the percentage of germination of southern seeds is very low as compared with that of seeds produced in northern climates. Seeds from different localities, even though they be of the same species, differ greatly in their responses to conditions which produce germination.

The yearly periodicity of *Tilia* seeds appears to be somewhat delayed as compared with other seeds of different species. It blossoms late, produces late fruit, and the seeds germinate only after a period of dormancy. Ewart states that plants from northern or southern climates strive to repeat their normal periodicity when placed in different climates. This late yearly periodicity of *Tilia*, which is probably a cold climate plant, and the very low temperature requirement for germination are due perhaps to some hereditary characteristics of the seed which prevent it from becoming absolutely acclimatized to its new environment.

Climatic factors play an important part in the production of *Tilia* seeds, and temperature appears to be the greatest of these factors. These seeds will after-ripen and germinate only at a low temperature. Rose has found that basswood seeds will after-ripen and germinate within eight months if they are kept at a low temperature of 5° to 10°C. Before germination can occur the hypocotyl, which remains alkaline during dormancy, must become acid. When a certain degree of acidity

has been reached within the entire embryo, water is imbibed more rapidly, the stored fats begin to break up into soluble foods, and the hypocotyl begins to push through the endosperm and testa. At this time the catalase content, the acidity, and the respiration rate are greatly increased. If the seeds are treated with a week acid before planting, the acidity of the embryo is greatly hastened and the rest period is shortened.

In this study seeds from northern and southern trees were used. A comparative study of the germination conditions of the northern and southern species was made along with a study of the conditions under which *Tilia* seeds in general would germinate.

The following facts have been noted:

1. Seeds of *Tilia* fail to after-ripen and germinate at room temperature after a period of six months. This temperature is too high to break the dormancy.

2. The seed coat is not the cause of dormancy, although it may lengthen the rest period. Seed coats at no time appear to be a limiting factor in the absorption of water.

3. Dormancy in *Tilia* seeds exists in the embryo or in the endosperm, probably in both.

4. Seeds with testas removed and with testas intact after-ripen and germinate at 5°C. A greater percentage of germination occurs at this temperature in seeds collected from northern trees than in seeds collected from southern trees. This is perhaps due to acclimatization.

5. Weak acids aid in breaking dormancy and in bringing about germination.

6. Freshly harvested seeds will after-ripen and germinate in less than five months when kept in moist storage (stratified) at 5°C. for 3 months and then treated with weak acid (HCl) before planting.

7. The catalase activity of seeds of *Tilia* varies directly as the rate of respiration. There is greater catalase activity in moist seeds stored at 5°C. than in seeds stratified at 5°C. Dry seeds stored at room temperature also contain a large percentage of catalase.

NORTH CAROLINA COLLEGE,
GREENSBORO, N. C.

THE BIRDS OF RALEIGH, N. C.

By C. S. Brimley

This list is based on my own records from 1884 to 1929, inclusive, aided very materially by observations and records communicated to me at various times by my brother, H. H. Brimley, Curator of the State Museum, Franklin Sherman, State Entomologist from 1900 to 1925, Stephen C. Bruner, now in Cuba, Z. P. Metcalf, Professor Entomology, State College, L. H. Snyder Associate Professor Zoology, State College, and some others.

All species on record from Wake county are included in the list and in addition I have added in parentheses a few which are on record from adjoining counties but not from Wake.

Only two other regions in North Carolina have as numerous a list of birds and these compare with Raleigh as follows,—

	RALEIGH	ASHEVILLE	NEWBERN-BEAUFORT
Swimmers and Waders	55	47	107
Land Birds	160	165	113
Totals	215	212	220

Other localities in the state from which we have reasonably good lists are Greensboro, 155 species; Durham, 145; Salisbury, 144; and Chapel Hill, 142. The figures for Asheville are based on Cairns' list, those for the New Bern-Beaufort region on Coues' with many additions, the Greensboro and Salisbury figures were furnished me by Mr. Elmer E. Brown of the former place, and the Durham and Chapel Hill figures are based on published lists with some additions (see Bibliography at end of paper).

The Raleigh species are divided according to seasonal occurrence and relative abundance into,

1. Permanent Residents	45 species
2. Summer Visitors	46 species
3. Winter Visitors	39 species
4. Transients	44 species
5. Stragglers	41 species
Total	215

Another grouping of our birds which is the one followed in the list is into,—

1. Swimmers	22 kinds
2. Waders	33 kinds
3. Gamebirds and Doves	4 kinds
4. Birds of Prey	19 kinds
5. Picarian Birds	16 kinds
6. Perchers	121 kinds

The last group comprises more than half the total number of birds on record.

The largest families are the Warblers (Mniotiltidae) with 35 species on record and the Finches (Fringillidae) with 28.

In these figures only full species are counted, that is where two or more subspecies of the same species occur, they are counted as only one species.

The vernacular or common names of the birds are alone used in this list as of late years they have become more stable than the scientific or so-called "Latin" names. The names used are those employed and indexed in the A. O. U. check list.

The earliest normal spring date and the latest normal autumn (or summer) date are given for all summer visitors, the earliest autumn and latest spring dates for winter visitors, the earliest and latest dates for both spring and fall for transients, while for breeders, which includes almost all residents and summer visitors, the earliest and latest dates for eggs are also given where known.

I. SWIMMERS

1. Holboell's Grebe. Nov. 2, 1924, L. H. Snyder.
2. Horned Grebe. Jan. 14, 1909, April 8, 12, 18, 1925, Oct. 2, 1916.
3. Pied-billed Grebe, "Diedapper," "Helldiver." Transient, March 14 to April 21, and August 7 to Oct. 5.
4. Loon. April 13, 1897, April 14, 1917, May 22, 1919, Nov. 17, 1887, Dec. 9, 1896. A coastwise bird straggling inland during the migrations.
5. Herring Gull. Observed by Dr. Snyder, March 27 to April 26 in 1925 to1927, also by Mr. Sherman, April 6, 1924. Hundreds of gulls were reported in the neighborhood of Raleigh after the heavy rains of late September, 1929, but none of us bird men were in the field at the time and so the species remains uncertain.

   (Bonaparte's Gull. A specimen was taken in Franklin County in Dec. 1889 by Mr. B. M. Moore of Raleigh.)
6. Sooty Tern. June 30, 1909, Aug. 2, 1926.
7. Black Tern. Scarce transient, Feb. 17, April 6 to May 10, July 28 to Sept. 23.

   (Common Tern. Observed at Durham by Mr. E. A. Seeman, in Oct. 1927 and Aug. 1928.)

8. White Pelican. One shot at the carp hatchery, May 12, 1884, by J. H. Coover.
   (Brown Pelican. One taken near Durham, May 20, 1912.)
9. Merganser (probably Red-breasted). Two seen by me on Lake Raleigh, April 27, 1926, that were much too large for the next.
10. Hooded Merganser. Nov. 24, 1888, Jan. 31, 1908.
11. Mallard. Winter visitor, Nov. 3 to April 21.
12. Black Duck. Winter visitor, Oct. 28 to April 7.
13. Baldpate. Nov. 12, 1891, April 25, 1892.
14. Greenwinged Teal. Winter visitor, Dec. 1 to April 13.
15. Bluewinged Teal. Transient, Oct. 19, 1888, Dec. 7, 1893, and March 23 to May 6.
16. Shoveller. A pair seen March 31, 1902.
17. Pintail. A pair seen on Lake Raleigh, Dec. 24, 1928.
18. Wood Duck. Resident, a brood of recently hatched young observed April 28, 1898.
19. Lesser Scaup Duck. "Little Blackhead." Winter visitor, rather common during spring migration, Nov. 7 to May 13, also a female seen June 1, 1900.
20. Bufflehead. Winter visitor, Dec. 16 to March 25.
21. Old Squaw. Jan. 14, 1910.
    (Other ducks recorded from near Durham by Mr. Seeman are the Redhead, Canvasback, Scaup or Big Blackhead and the Ruddy Duck.)
22. Wild Goose. Used to be not infrequently seen during the migrations. Observed by Dr. Snyder on Lake Raleigh on Feb. 17 and Nov. 2, 1924.
    (Whistling Swan. A small flock observed by Seeman near Durham in winter of 1927.)

II. WADERS

23. Wood Ibis. A flock observed and one killed in July, 1884; one killed on Buffalo's Pond, July 4, 1906; from one to six seen and one taken, on Lake Raleigh, July 2 to 11, 1927. (One taken at Chapel Hill, June 12, 1901, G. M. MacNider.)
24. Bittern. Mostly spring transient, March 26 to May 29, also Sept. 20, 1928, and Dec. 7, 1886.
25. Least Bittern. Summer visitor, May 3 to Nov. 24; eggs taken May 30 to July 1.
26. Great Blue Heron, "Blue Crane." Occurs sparingly all the year, commonest in late March and April, not known to breed.
    (Great White Heron. One killed on Crystal Lake near Durham, July 8, 1926, by unknown negro and saved for preservation by boy scouts. The skin is now preserved unmounted in the State Museum.)
27. Egret. June 25, 1917, July 15, 1884, July 17, 1927, Aug. 16, 1921.
28. Louisiana Heron. One seen on Lake Raleigh, July 7, 1927.
29. Little Blue Heron, "Little White Heron." After the breeding season is over, the young in white plumage scatter all over the state. June 14 to Oct. 8.
30. Green Heron, "Indian Hen," "Scout," "Shypoke," "Fly-up-the-creek." Summer visitor, March 26 to Oct. 5, eggs April 29 to July 9.

31. Blackcrowned Night Heron. Scarce spring transient, April 6 to April 17.
32. Yellowcrowned Night Heron. Scarce spring transient, April 2 to April 16, also immature birds taken in summer, June 25 to July 14.
33. King Rail, "Marsh Hen." Summer visitor, late March to November, also occasional in winter. Eggs, May 10 to July 20.
34. Virginia Rail. Transient, March 7 to May 9, and Sept. 8 to Oct. 9.
35. Sora. Transient, April 8 to May 13, Aug. 21 to Oct. 17.
36. Black Rail. Summer visitor, eggs May 27 to July 12. This is a skulking species and is very seldom seen.
37. Purple Gallinule. June 3, 6, 1887. Have also had several reports of birds that seemed to be this.
38. Florida Gallinule. Occasional during migration, April 20, 1907, May 30, 1916, Sept. 21, 1918, Nov. 9, 1929. Both this and the preceding may breed in this vicinity.
39. Coot. Scarce transient, April 5 to May 16, Oct. 28 to Dec. 1.
40. Woodcock. Resident, eggs March 3 to April 11.
41. Wilson's Snipe. Winter visitor, but by far commonest in the spring migration, Sept. 20 to May 7.
42. Dowitcher. One killed on the carp ponds. July 29, 1884.
43. Pectoral Sandpiper. Transient, March 22 to April 15, Nov. 15, 1894.
44. Whiterumped Sandpiper. May 22, 24, 1909.
45. Least Sandpiper. Spring transient, April 30 to May 24.
46. Semipalmated Sandpiper. Spring transient, April 13 to May 22.
47. Greater Yellowlegs. Spring transient, March 22 to May 29.
48. Yellowlegs. Spring transient, March 25 to May 18, also Aug. 17, 1918.
49. Solitary Sandpiper. Transient, April 4 to May 27, July 14 to Oct. 10.
50. Ruff. A female taken by H. H. Brimley, May 6, 1892. This is a straggler from Europe.
51. Bartramian Sandpiper or Upland Plover. Spring transient, March 28 to April 30, formerly rather common.
52. Spotted Sandpiper. Summer visitor, much commonest during the spring migration, April 7 to Sept. 27. On Sept. 27, 1929, a specimen was taken that had been banded at Zion, Ill., the past summer.
53. Golden Plover. One killed in fall of 1884 by W. S. Primrose.
(Lapwing. One killed in Chatham County, Nov. 12, 1926, by E. T. Noel. It is now mounted in the State Museum. A large flight of these European birds was reported on the New England coast about the same time.)
54. Killdeer. Resident, eggs April 2 to June 22.
55. Semipalmated Plover. May 5, 14, 1884, May 22, 1909.

III. GAME BIRDS AND DOVES

56. Bobwhite, "Partridge," "Quail." Resident.
56a. Texan (Mexican) Bobwhite. Quite a number of these birds have been released in the past year or two from northern Mexico.
57. Wild Turkey. Resident, no longer common.
58. Passenger Pigeon. Observed by H. H. Brimley, April 18, 1891. (Dr. K. P. Battle, Jr., of Raleigh told me some years ago that when at Bingham School, he saw a flock of these birds about a mile wide in 1873 (about), and that he killed one out of a flock of three at Chapel Hill in 1878.)

59. Mourning Dove. Resident, eggs April 11 to June 21.
(Ground Dove. One taken in Johnston county near Four Oaks, Dec. 23, 1919, by Lonnie Lassiter.)

IV. BIRDS OF PREY

60. Turkey Vulture, "Turkey Buzzard." Resident, eggs April 19 to June 12.
61. Black Vulture, "South Carolina Buzzard." Resident, eggs April 6 to April 20.
62. Marsh Hawk, "Rabbit Hawk." Winter visitor, Aug. 15 to April 29.
63. Sharpshinned Hawk. Resident, commonest in winter.
64. Cooper's Hawk. Resident, eggs April 30, 1895. This and the preceding are locally known as "Bluetailed Darters," prey exclusively on small birds, including young chickens and are almost entirely responsible for the bad reputation of all hawks.
65. Redtailed Hawk. Resident, larger but less common than the next.
66. Redshouldered Hawk. Resident, eggs March 25 to April 28. This and the preceding are usually called "Chicken Hawks" although this species does not attack them at all and the Redtail only occasionally.
67. Broadwinged Hawk. Summer visitor, April 8 to Sept. 14, eggs April 22 to May 22.
(Swallowtailed Kite. Two seen about thirty years ago near Durham according to E. A. Seeman.)
68. Bald Eagle. Adults seen flying over Raleigh on April 6, 1919, and Aug. 6, 1924; specimens taken on April 26, 1927, and May 3, 1925.
69. Pigeonhawk. Transient, scarce, April 21 to April 29, Sept. 2 to Oct. 21.
70. Sparrowhawk. Resident, breeds in hollow trees.
71. Osprey, "Fish Hawk." Transient, March 5 to May 11, Aug. 25 to Oct. 5.
72. Barn Owl, "Monkey-faced Owl." Probably resident, but only recorded in Jan., Feb., April. An expert mouser.
73. Longeared Owl. Winter visitor, scarce, Dec. 11 to Feb. 24.
74. Shorteared Owl. Winter visitor, Nov. 8 to Feb. 9.
75. Barred Owl. Resident, eggs March 14 to April 9.
76. Sawwhet Owl. Winter visitor, three records, all in December, our smallest owl.
77. Great Horned Owl. Resident, eggs March 9 and March 26.
78. Screech Owl. Resident, common, both red and grey phases occur.
(Snowy Owl. Taken in Granville county, Jan. 7, 1902, and in Nash County, late Nov., 1909. A straggler from the far north, only to be looked for in cold winters.)

V. THE PICARIAN BIRDS

79. Yellowbilled Cuckoo, "Raincrow." Summer visitor, April 28 to Oct. 17, eggs June 7 to July 27.
80. Blackbilled Cuckoo. Summer visitor, April 21 to Oct. 10, much less common than preceding and mostly during the migrations.
81. Belted Kingfisher. Resident.
82. Southern Hairy Woodpecker. Resident, shy and rather scarce.
83. Southern Downy Woodpecker. Resident.

84. Redcockaded Woodpecker. April 22, 1891, April 28, 1898, also observed by Bruner, but I do not have the date.
85. Yellowbellied Sapsucker. Winter visitor, Sept. 27 to April 29, the only sapsucking woodpecker. Digs innumerable little holes in the tender bark of apple, maple, yellow pine and possibly other trees.
86. Pileated Woodpecker, "Logcock." Resident, scarce and getting scarcer as the heavy timber is cut down. Last record May 9, 1919.
87. Redheaded Woodpecker. Resident, feeds largely on small acorns.
88. Redbellied Woodpecker. Resident, less common than preceding, most frequent in timber along streams.
89. Flicker. Resident, eggs in May. Locally called "Yellowhammer."
90. Chuckwillswidow. Summer visitor, April 10 to September 21, eggs May 13.
91. Whippoorwill. Summer visitor, March 16 to Nov. 6, eggs April 29 to June 10.
92. Nighthawk, "Bullbat." Summer visitor, but much commonest in the autumn migration; April 15 to Oct. 6, eggs in June.
93. Chimney Swift, "Chimney Sweep," "Chimney Swallow." Summer visitor, April 3 to Oct. 14.
94. Rubythroated Hummingbird. Summer visitor, April 9 to Oct. 8, eggs May 7 to July 5.

V. THE PASSERINE OR SONGBIRDS.

A. Flycatchers to Orioles.

95. Kingbird, "Bee martin." Summer visitor, April 12 to Oct. 5, eggs May 28 to June 25.
96. Crested Flycatcher. Summer visitor, April 9 to Oct. 12, eggs May 23 to June 23. Nests in a hollow in a tree.
97. Phoebe. Resident, least common in summer, eggs in April.
98. Wood Pewee. Summer visitor, April 18 to Oct. 13, eggs May 25 to June 11.
99. Acadian Flycatcher. Summer visitor, April 20 to Sept. 11, eggs May 23 to June 25.
100. Traill's Flycatcher. Transient, May 14, 16, 1892, Aug. 27, 1898, Sept. 21, 1893.
101. Horned Lark. Winter visitor, but only in cold winters or cold snaps. Dec. 7 to Feb. 20, in winters of 1886–7, 1892–3, 1894–5, 1916–7, 1917–8.
101a. Prairie Horned Lark. A slightly different race furnishing the majority of the specimens observed here in the above named winters, the two are not distinguishable in the field.
102. Blue Jay. Resident.
103. Crow. Resident.
104. Starling. Resident, introduced, first observed April 19, 1923, now common.
105. Bobolink, "Ricebird." Transient, April 17 to May 27, Aug. 15 to Oct. 12.
106. Cowbird. Winter visitor, Sept. 4 to April 29, about thirty years ago was exceedingly abundant for several years in March and early April.
107. Redwinged Blackbird. Resident, eggs May 10 to June 9.
108. Meadow Lark. Now resident, up to 1916 we considered it a winter visitor, one previous date only being possibly of summer birds (Aug. 8, 1887).
109. Orchard Oriole. Summer visitor, April 16 to Aug. 22, eggs May 20 to June 11.

110. Baltimore Oriole. Transient, scarce, April 26 to May 12, Aug. 31 to Sept. 17.
111. Rusty Blackbird. Transient, Feb. 15 to April 26, Oct. 17 to Dec. 16.
112. Purple Grackle, "Crow Blackbird." Winter visitor, Oct. 26 to April 24, also once taken June 16, 1891.
112a. Bronzed Grackle. March 3 and Feb. 26 in spring and from Nov. 5 to Dec. 11 in fall. Only observed in six years, and not distinguishable in field from preceding.

B. The Finch or Sparrow Family.

113. Purple Finch. Winter visitor, Oct. 28 to April 27.
114. Crossbill. Very irregular straggler, Jan. 16, 26, Feb. 8, 1897. March 11, 23, 1885, May 9, 1907, June 5, 1887, Nov. 8, 1919.
115. Whitewinged Crossbill. Three killed by S. C. Bruner, Feb. 23, 1907.
116. Goldfinch, "Wild Canary." Resident.
117. Siskin. Winter visitor, irregular, Nov. 3 to May 11, has been observed in eight different winters, last being 1923.
(Evening Grosbeak. Taken at Chapel Hill by W. C. Coker, March 8, 1922, and observed at Salisbury by E. E. Brown and others on March 25 and April 1 of same year.)
118. English Sparrow. Resident, introduced, first appeared in Raleigh about 1880.
119. Lapland Longspur. Jan. 13, 14, 1893, Feb. 20, 1895, in company with Horned Larks.
120. Vesper Sparrow. Winter visitor, Oct. 11 to April 27.
121. Savanna Sparrow. Winter visitor, Sept. 16 to May 13.
122. Grasshopper Sparrow. Summer visitor, April 13 to Oct. 22, also on March 25, 1897.
123. Henslow's Sparrow. Spring transient, March 22 to May 3, observed in seven different years.
124. Leconte's Sparrow. April 21, 1894, one. A straggler from the west.
125. Lark Sparrow. Aug. 19, 1889, Oct. 25, 1893. Deserted nest with eggs, July 24, 1890. Another western bird.
126. Whitecrowned Sparrow. April 14, 1912, one taken by Bruner; also one taken about 1884 by J. L. Busbee.
127. Whitethroated Sparrow. Abundant winter visitor, Oct. 4 to May 18.
128. Chipping Sparrow. Common summer visitor, Feb. 23 to Nov. 25, also taken Dec. 29, 1890. Eggs May 15 to June 26.
129. Field Sparrow. Resident, eggs May 4 to July 27.
130. Slatecolored Junco, "Snowbird." Winter visitor, Oct. 23 to April 24.
131. Bachman's Sparrow, Summer visitor, scarce, March 19 to Sept. 20.
132. Song Sparrow. Winter visitor, Oct. 4 to April 29.
133. Swamp Sparrow. Winter visitor, Oct. 10 to May 18.
134. Fox Sparrow. Winter visitor, not common, Oct. 17 to April 6.
135. Towhee, "Joreeper," "Joree." Winter visitor, commonest in the migrations, Oct. 4 to May 17.
136. Cardinal, "Redbird." Resident, eggs May 8 to July 2.
137. Rosebreasted Grosbeak. Spring transient, scarce, April 22 to May 8.

138. Blue Grosbeak, "Big Indigo." Summer visitor, April 24 to Sept. 27, eggs May 31 to July 16.
139. Indigo Bunting, "Little Indigo." Summer visitor, April 19 to Oct. 19, eggs May 21 to July 13.
140. Dickcissel, "Blackthroated Bunting." A pair seen and heard on May 17, 1928, in a wheat field near State College by L. H. Snyder, L. A. Whitford and myself.

C. Tanagers to Vireos.

141. Scarlet Tanager. Transient, April 19 to May 14, Sept. 8 to Oct. 14.
142. Summer Tanager, "Summer Redbird." Summer visitor, April 6 to Sept. 30, eggs May 30 to June 16. Feeds largely on wasps and bees.
143. Purple Martin, "Black Martin," "Gourd Martin." Summer visitor, March 16 to Sept. 1. Except around nesting colonies is much commonest in the fall migration.
144. Barn Swallow. Transient, April 2 to May 25, Aug. 5 to Sept. 16.
145. Cliff Swallow. Transient, scarce, April 13 to May 17.
146. Tree Swallow. Transient, March 12 to May 30, also observed in 1888 from Sept. 7 to Oct. 13.
147. Bank Swallow. April 24, 1888, Aug. 8, 1894.
148. Roughwinged Swallow, "Bank Swallow." Summer visitor, March 28 to July 27, eggs May 15 to June 12. The common "Bank Swallow" of the South as the preceding is of the North.
149. Cedar Waxwing. Irregular at all seasons, the data I have at present only gives it from Oct. 26 to June 15. Eggs taken once on June 13, 1890.
150. Loggerhead Shrike, Winter visitor, Aug. 18 to April 1. Our form is the subspecies known as the Migrant Shrike.
151. Redeyed Vireo, "Hanger." Summer visitor, April 6 to Oct. 16, eggs May 19 to June 17.
152. Yellowthroated Vireo. Summer visitor, April 3 to Sept. 16, eggs May 28, 1894. Common in shade trees in town.
153. Blueheaded Vireo. Summer visitor, commonest in the migrations, March 12 to Nov. 15, also once in December and once in January. Eggs April 27, 1891, and April 20, 1924.
154. Whiteeyed Vireo. Summer visitor, March 25 to Oct. 16 and once on March 3. Eggs April 26 to June 27.

D. The American Warblers.

155. Black and White Warbler. Summer visitor, March 21 to Oct. 13, also once in mid-November. Eggs May 12, 1893.
156. Prothonotary Warbler. Summer visitor, April 18 to Aug. 25, apparently breeds in the cypress swamp near Eagle Rock.
157. Wormeating Warbler. Summer visitor, April 19 to Sept. 20.
158. Bachman's Warbler. April 27, and May 22, 1891, two males.
159. Bluewinged Warbler. Transient, scarce, April 26 to May 6, Aug. 20 to Sept. 4.
160. Goldenwinged Warbler. Transient, May 7, 1886 and 1891, Aug. 26, 1886, Aug. 30, 1893.

161. Brewster's Warbler. Sept. 6, 1888.
162. Tennessee Warbler. Fall transient, Sept. 12 to Oct. 7 in 1887–9.
163. Parula Warbler. Summer visitor, much commonest during the migrations. March 29 to Oct. 20.
163a. Northern Parula Warbler. Occasional during the migrations.
164. Cape May Warbler. Transient, all spring dates except April 7, 1892, fall between April 22 and May 9, once in fall on Nov. 1, 1911.
165. Yellow Warbler. Summer visitor, April 5 to Sept. 20.
166. Blackthroated Blue Warbler. Transient, April 17 to May 19, Sept. 16 to Oct. 23, also once in mid-November.
167. Myrtle Warbler. Winter visitor, Oct. 11 to May 18.
168. Magnolia Warbler. Transient, not common, May 10 to May 17, Sept. 11 to Oct. 20.
169. Cerulean Warbler. Once in spring, May 8, 1893, three times in fall, Aug. 29, 1889, Sept. 16, 1887, and 1916.
170. Chestnutsided Warbler. Transient, April 27 to May 15, Aug. 17 to Oct. 12.
171. Baybreasted Warbler. May 5, 1915, S. C. Bruner.
172. Blackpoll Warbler. April 16 to June 3, Sept. 24 to Nov. 5, the latest of the transient warblers at both seasons.
173. Blackburnian Warbler. Fall transient, Aug. 25 to Oct. 13. Has been taken near Durham in spring.
174. Yellowthroated Warbler. Summer visitor, March 13 to Sept. 20, eggs April 22 to June 7.
175. Blackthroated Green Warbler. Transient, March 22 to May 22, Sept. 7 to Oct. 16.
175a. Wayne's Warbler. This is the form of the preceding which breeds in the cypress swamps of both Carolinas, including probably that near Eagle Rock. The early spring records certainly belong to this form. The bird referred to on page 295 of the "Birds of North Carolina" belongs here.
176. Pine Warbler. Resident, eggs March 20 to May 24.
177. Palm Warbler. May 1, 1893. Perhaps some of the records of the next also belong here.
177a. Yellow Palm Warbler. Winter visitor, commonest at various times during the migrations. Sept. 16 to April 27.
178. Prairie Warbler. Summer visitor, April 6 to Sept. 20, eggs May 12 to June 11.
179. Ovenbird. Summer visitor, April 2 to Oct. 23.
180. Water Thrush. Transient, April 18 to May 28, July 25 to Oct. 6.
181. Louisiana Water Thrush. Summer visitor, March 14 to Aug. 4, eggs April 29 to May 19.
182. Kentucky Warbler. Summer visitor, April 18 to Oct. 13, nest with young, June 12, 1908, S. C. Bruner.
183. Connecticut Warbler. Fall transient, scarce, Sept. 28 to Oct. 4.
184. Maryland Yellowthroat. Summer visitor, March 20 to Oct. 24, also Dec. 6, 1889, Jan. 8, 1891, Jan. 30, Feb. 4, 1890, Feb. 7, 1889. Eggs May 13 to July 4.
185. Yellowbreasted Chat, "Pompey." Summer visitor, April 18 to Sept. 13, eggs May 15 to July 2.
186. Hooded Warbler. Summer visitor, April 5 to Oct. 1.
187. Wilson's Warbler. May 17, 1887, May 13, 1892, May 11, 16, 1893, May 19, 1915.

188. Canadian Warbler. May 13, 1892, May 18, 1912.
189. Redstart. Summer visitor, April 2 to Oct. 13, eggs in mid-May.

E. Pipits to Thrushes

190. Pipit. Winter visitor, Oct. 17 to April 6.
191. Mockingbird. Resident, less common in winter, eggs May 8 to July 5.
192. Catbird. Summer visitor, April 13 to Nov. 17, also three times in January and once in February. Eggs May 24 to June 10.
193. Brown Thrasher. Resident, not common in winter. Eggs April 27 to July 6. Common from March to September.
194. Carolina Wren. Resident, the only bird that sings all the year; eggs April 15 to July 31.
195. Bewick's Wren. Winter visitor, not common, Sept. 24 to April 3.
196. House Wren. Transient, April 10 to May 23, Sept. 25 to Oct. 16. A pair started to breed here in late May, 1923. Until recent years not known as a breeding bird in the state, but since 1922 has been observed breeding at Greensboro, Salisbury and Durham by E. E. Brown and others.
197. Winter Wren. Winter visitor, Sept. 26 to April 27.
198. Shortbilled Marsh Wren. May 4, 1892, Aug., 10, 1894.
199. Longbilled Marsh Wren. Erratic transient, April 21 to May 7, Sept. 20 to Oct. 19, also noted three times in March and twice in January.
200. Brown Creeper. Winter visitor, Oct. 3 to April 19.
201. Whitebreasted Nuthatch. Resident, usually seen singly or in pairs.
202. Redbreasted Nuthatch. Winter visitor, irregular in occurrence, and observed in only fourteen winters out of forty-six. Sept. 13 to April 24.
203. Brownheaded Nuthatch. Resident, eggs March 24 to May 15. This and the preceding usually seen in family groups of about half a dozen.
204. Tufted Tit. Resident, eggs April 28 to June 8.
205. Carolina Chickadee, "Tomtit." Resident, eggs April 3 to May 11.
206. Goldcrowned Kinglet. Winter visitor, Oct. 7 to April 19, usually in troops.
207. Rubycrowned Kinglet. Winter visitor, Oct. 1 to May 10, usually singly or in pairs. Commonest in spring migration.
208. Bluegray Gnatcatcher. Summer visitor, March 16 to Oct. 2, eggs April 28 to June 18.
209. Wood Thrush, "Swamp Robin." Summer visitor, April 10 to Oct. 16, eggs May 7 to June 16.
210. Veery or Wilson's Thrush. Transient, April 23 to May 9, Aug. 28 to Sept. 18.
211. Olivebacked Thrush. Transient, April 22 to May 17, Sept. 26 to Oct. 17.
212. Graycheeked Thrush. Transient, May 4 to May 24, Oct. 2 to Oct. 12.
212a. Bicknell's Thrush. Transient, May 3 to May 18, Sept. 24 to Oct. 12. A smaller form of preceding with different breeding range.
213. Hermit Thrush. Winter visitor, Oct. 16 to April 29.
214. Robin. Resident as a species but the typical or northern robin occurs with us only during the migrations and in winter, very irregularly at both seasons.

214a. Southern Robin. Our breeding robins belong to this doubtfully different form. The robin is a common breeder here now, whereas until comparatively recent years it was a very scarce one. Breeding birds seem to arrive in March and leave in September. Eggs have been observed in April.

215. Bluebird. Resident, eggs April 13 to June 26. This species was almost exterminated at Raleigh and in the Eastern States generally by the blizzard of February, 1895, but has now regained its old numbers.

The above list includes seven birds which have been added to those known from the state since the publication of "The Birds of North Carolina" in 1919 as volume IV of the Reports of the North Carolina Geological and Economic Survey. They are the Great White Heron, Lapwing, Mexican Bob White, Starling, Evening Grosbeak, Dickcissel, and Wayne's Warbler. In addition to these, three others have been added to the state's list from more remote counties. They are:

Hutchin's Goose (*Branta canadensis hutchinsi* (Rich.). Taken on Currituck Sound in 1888 (McAtee, Auk **43**: 251–2. 1926). This is a smaller form of the Canada Goose, breeding in arctic and subarctic America and not usually occurring in the United States east of the Alleghanies.

Roseate Spoonbill (*Ajaja ajaja* (L.)). One seen near Smith's Island in the spring of 1919 by Edward Fleischer of Brooklyn, N. Y. (E. F. in letter to T. G. Pearson, April 17, 1919).

Florida Barred Owl (*Strix varia alleni* (Ridg.)). One taken on Pamlico River, three miles from Bath, January 16, 1930, by Dr. Alexander Wetmore.

DEPARTMENT OF AGRICULTURE,
RALEIGH, N. C.

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THE BALD CYPRESS

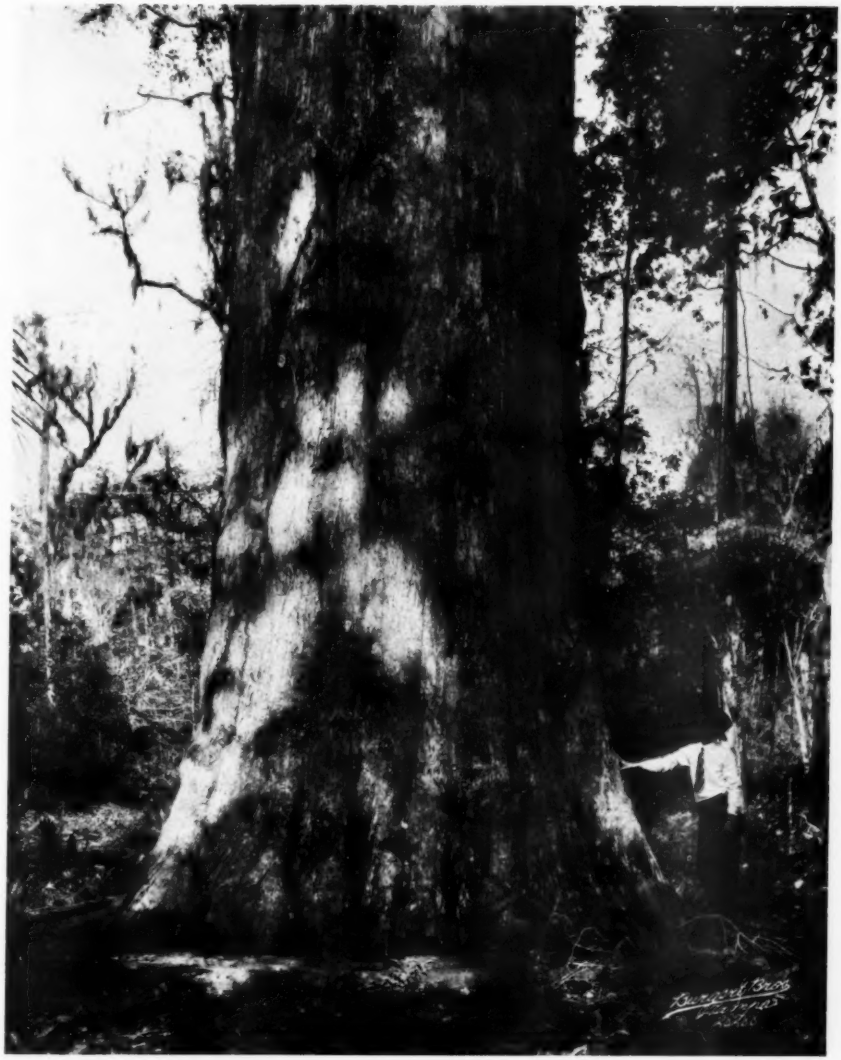
By W. C. Coker

Plate 7

For some time we have been trying to get records of the largest individual trees of the more important species in the South Atlantic States. The largest tree that I have seen east of the Mississippi is a bald cypress near Longwood, Seminole County, Florida (see photograph published herewith). The total height is 126.33 ft., and it measures 42.9 ft. in circumference (diameter 13.65 ft.) 18 inches from the ground. It has a circumference of 25.2 ft. (diam. 8.2 ft.) at 62 ft. from the ground. It has a clear trunk of 72 ft. which has been calculated by lumbermen to have an average diameter of 9 ft. This will make, according to their estimates, 1756 cross ties of 722,601 shingles. (Figures transmitted by Mr. D. G. Coit of Jacksonville.) It will be noticed that the most impressive thing about this tree is the immense thickness throughout its height. The impression of massiveness given by the entire tree is very nearly that given by the average "Big Tree" of California, and when I saw it I could hardly believe that I was in the eastern states. A few individuals of other species approach the circumference of this tree near the ground, but none that I have ever heard of in these states approach its total mass.

The age of the immense tree in Florida is not known, as no borings have been made, but I think it would be a conservative estimate to say that it is at least 1500 years old. In addition to newspaper reports, we know of two articles which have appeared on this Sovereign Cypress of Seminole County. One is by Lloyd Logan (American Forests and Forest Life **35:** 417. 1929). It is accompanied by a photograph showing most of the trunk. The figures there given for the circumference and diameter are much larger than our records and must have been measured at the very base of the tree. They give a wrong impression of the size. Prof. Herman Kurz of Florida has also written about this tree (Beautiful Florida **6:** 8. 1929). He gives the circumference as 47 feet, 11 inches, at the base.

PLATE 7



SOVEREIGN CYPRESS OF SEMINOLE COUNTY, FLORIDA.
Courtesy of Mr. D. E. Coit. Photograph by Burgert Bros.

In Lenoir County, N. C., a cypress tree was cut about 1914 having a diameter of 11 ft. 1 in. at 4 ft. from the ground. Twenty feet from the ground the diameter was 5.37 ft. and showed 818 rings (figures by Mr. H. H. Brimley; see Conservation and Industry **6**: 8. 1929). The botanical department of the University of North Carolina received last spring through the kindness of the Cummer Cypress Company of Jacksonville, Florida, a section of a cypress tree taken from near the ground but above the main basal spread, which is 6.5 ft. thick and shows about 950 rings (the very center is decayed). This is now on exhibit here.

The next largest trees in these states seem to be the sycamore and tulip poplar. The so-called Sugar Creek Camp tulip tree, near the place where Elisha Mitchell fell, was 33 ft. in circumference 3 ft. above ground, as measured by the well-known botanist, W. M. Canby, in 1866 (Sargent's Silva **1**: 19). It is still standing and in good health, I hear. At Reems Creek, N. C., is a poplar 34.5 ft. at 4 ft. above ground (figures by Mr. John R. Hess, transmitted to us by Mr. J. S. Holmes).

Records in regard to large sycamores show them to be superior in size to any other tree of the eastern states near the ground levels. The two largest recorded that we know of are those reported by Michaux and Case. Michaux says that one by the Ohio River 36 miles from Marietta was 47 ft. in circumference 4 ft. above ground (Travels West of the Alleghany Mountains, 1805); and Case gives one in the valley of the White River near Worthington, Indiana, as "48 ft. in circumference," evidently measured near the ground (Bot. Gaz. **5**: 70. 1880). A very large sycamore growing in Indiana across the Wabash from Mt. Carmel, Illinois, is illustrated in American Forests and Forest Life **36**: 510. 1930. It is the only one left of a magnificent grove measured by Dr. Robert Ridgway about 60 years ago. The largest apparently was 30 ft. in circumference, measured above the basal swell.

Some years ago Gulf State papers published stories about a large cypress called the Edenborn Brake Cypress in Louisiana. I have not been able to get any reliable data, however, concerning it. One paper said Prof. Herman von Schrenk estimated its age at 2500 years, but in a letter to me von Schrenk would not confirm this and gave no guess. There is said to have been a section of it in the Dept. of Forestry of Louisiana, but Prof. Marckworth of the University Forestry department writes me that the section has disappeared.

The bald cypress is in many ways one of the finest trees in the country. Aside from its well known value as a timber tree and great resistance to deterioration it is, contrary to general opinion, easily cultivated in the

uplands, where it makes one of the most beautiful of all ornamentals. In ordinary fairly dry soil, the knees are not formed, but they are formed in moist places without standing water. Quite contrary to what one would expect, the tree seems rather resistant to the unfavorable environment of cities. In the Bulletin New York Botanical Garden **14:** 136, 1929, Mr. Edmund H. Fulling calls attention to a tree at the corner of 13th and Locust streets in Philadelphia, in the heart of the city, that is 60 ft. high and in healthy condition. It stands in an opening 30 inches square, but otherwise completely surrounded by brick or asphalt.

The cypress would certainly be worth trying as a street tree in our towns and cities. If successful, nothing more beautiful could be imagined than an avenue of this magnificent tree.

UNIVERSITY OF NORTH CAROLINA,
CHAPEL HILL, N. C.

DIATOMS OF BEAUFORT[1]

By the late JAMES J. WOLFE

EDITED BY BERT CUNNINGHAM

For several years prior to his untimely death in 1920, Dr. J. J. Wolfe studied the diatom flora of Beaufort. During this time he assembled a fairly large collection of representative forms of the region.

In addition to the mounting and studying of specimens he prepared, with the assistance of an artist, Mrs. Decker, some exceedingly well done retouched microphotographs of numbers of specimens. He furthermore carefully compiled a synonymy for the forms observed.

This work was cut short by death. However a splendid set of notes was left and the second author sought to place these together into a systematic order. This made a report of some 150 pages exclusive of any figures.

Since this work is incomplete, and deals in general with the more common forms, and since the descriptions and figures are available elsewhere, it was suggested by Dr. A. Mann, to whom the matter was referred by the Bureau of Fisheries, that only the list of forms occurring at Beaufort be published.

While the junior author believes that the whole of the manuscript should be published, because of certain evident disagreements with Mann in the manuscript, especially as related to synonomy, he is willing to agree to publication since this list of the forms occurring at Beaufort would serve as an excellent basis for further study. Furthermore, there is being placed on file in the Duke University Library a typewritten copy of the complete manuscript. The mounted specimens which were sent to Mann for confirmation and correction have been placed by him in the Smithsonian Collections. The photographs are in custody of the Bureau of Fisheries at Washington.

The following list of genera and species have been confirmed by Mann and his assistant, Mr. Conger. Where disagreements have occurred between Wolfe and Mann, the latter has always been accepted in this list, but disagreements are noted on the original manuscript.

[1] This work was done largely at the U. S. Fisheries Laboratory at Beaufort and was aided by grants from the Fisheries and also Duke University.

LIST OF GENERA OF DIATOMS IN THE VICINITY OF BEAUFORT, NORTH CAROLINA

1. Achnanthes
2. Actinocyclus
3. Actinoptychus
4. Amphiprora
5. Amphora
6. Aulacodiscus
7. Auliscus
8. Bellerochea
9. Biddulphia
10. Campylodiscus
11. Cerataulina
12. Chaetoceras
13. Coscinodiscus
14. Cyclotella
15. Cymatopleura
16. Cymatosira
17. Diatoma
18. Dictyoneis
19. Dimmeragramma
20. Diploneis
21. Ditylum
22. Donkinia
23. Eucampia
24. Eunotia
25. Eunotogramma
26. Eupodiscus
27. Grammatophora
28. Hantzschia
29. Hemiaulus
30. Huttonia
31. Hyalodiscus
32. Licmophora
33. Lithodesmium
34. Mastogloia
35. Melosira
36. Navicula
37. Nitzschia
38. Opephora
39. Plagiogramma
40. Pleurosigma
41. Pseudo-Auliscus
42. Rhabdonema
43. Rhaphoneis
44. Rhizosolenia
45. Rhoicosphenia
46. Roperia
47. Scoliopleura
48. Stephanopyxis
49. Surirella
50. Thalassiosira
51. Thalassiothrix
52. Terpsinoe
53. Trigonium
54. Tropidoneis

LIST OF SPECIES OF DIATOMS IN THE VICINITY OF BEAUFORT, NORTH CAROLINA

1. Achnanthes brevipes Ag.
2. Actinocyclus alienus Grun. var. arctica Grun.
3. Actinocyclus Barklyi (Ehr.) Grun.
4. Actinocyclus crassus (W. Sm.) Ralfs
5. Actinocyclus Ehrenbergii Ralfs
6. Actinocyclus tenellus Breb.
7. Actinoptychus hexagonus Grun. var tenella A. S.
8. Actinoptychus hispidus Grun.
9. Actinoptychus Janischii Grun.
10. Actinoptychus splendens (Shad.) Ralfs
11. Actinoptychus undulatus (Bail.) Ralfs
12. Actinoptychus vulgaris Schum.
13. Amphiprora conspicua Grev.
14. Amphiprora pulchra Bail.
15. Amphiprora sulcata O'Me.
16. Amphora compacta Mann
17. Amphora egregia (Ehr.) A. S.

18. Amphora intersecta (?) A. S.
19. Amphora proteus Greg. var.
20. Aulacodiscus Argus (Ehr.) A. S.
21. Auliscus accedens Ratt.
22. Auliscus caelatus Bail.
23. Auliscus Mannii Wolfe
24. Auliscus pruinosus Bail.
25. Auliscus punctatus Bail. var.
26. Auliscus radiatus Bail.
27. Auliscus Schmidtii Gründ.
28. Auliscus Stockhardtii Jan. var.?
29. Bellerochea malleus (Brightw.) V. H.
30. Biddulphia antediluviana (Ehr.) V. H.
31. Biddulphia Favus (Ehr.) V. H.
32. Biddulphia granulata Roper
33. Biddulphia mobiliensis (Bail.) Grun.
34. Biddulphia patagonica (A. S.) Conger.
35. Biddulphia pentacrinus (Ehr.) Boyer
36. Biddulphia polymorpha (Kütz.) V. H.
37. Biddulphia pulchella Gray
38. Biddulphia regina W. S.
39. Biddulphia rhombus (Ehr.) W. S.
40. Biddulphia rhombus (Ehr.) W. S. var. trigona Cl.
41. Biddulphia sculpta (Shad.) V. H.
42. Biddulphia setigera (Bail.) Mann
43. Biddulphia Smithii (Ralfs) V. H.
44. Biddulphia Tuomeyi (Bail.) Roper
45. Biddulphia turgida (Ehr.) W. S.
46. Campylodiscus concinnus Grev.
47. Campylodiscus Echeneis Ehr.
48. Campylodiscus imperialis Grev.
49. Campylodiscus latus Shad.
50. Cerataulina Bergonii H. Perag.
51. Chaetoceras affine Laud.
52. Chaetoceras boreale Bail. var.
53. Chaetoceras coarctatum Laud.
54. Chaetoceras constrictum Gran.
55. Chaetoceras convolutum? Cast.
56. Chaetoceras criophilum Cast.
57. Chaetoceras criophilum Cast. var. volans. Schutt
58. Chaetoceras currens? Cl.
59. Chaetoceras curvisetum Cl.
60. Chaetoceras danicus? Cl.
61. Chaetoceras decipiens Cl
62. Chaetoceras densum Cl.
63. Chaetoceras diadema? (Ehr.) Gran.
64. Chaetoceras distans Cl.
65. Chaetoceras diversum? Cl.

66. Chaetoceras Lorenzianum Grun.
67. Chaetoceras pelagicum Cl.
68. Chaetoceras Peruvianum Brightw.
69. Chaetoceras teres Cl.
70. Chaetoceras (Bacteriastrum) varians (Laud.) V. H.
71. Coscinodiscus apiculatus Ehr.
72. Coscinodiscus asteromphalus Edw.
73. Coscinodiscus biangulatus A. S.
74. Coscinodiscus concinnus W. S.
75. Coscinodiscus cristatus Ratt. var. distans Ratt.
76. Coscinodiscus curvatulus Grun. var.
77. Coscinodiscus decrescens Grun.
78. Coscinodiscus excentricus Ehr.
79. Coscinodiscus marginatus Grun.
80. Coscinodiscus marginulatus Ratt.
81. Coscinodiscus nitidus Greg.
82. Coscinodiscus nobilis Grun.
83. Coscinodiscus obversus Ratt.
84. Coscinodiscus oculus-iridis Ehr.
85. Coscinodiscus oculus-iridis Ehr. var. borealis Bail.
86. Coscinodiscus radiatus Ehr.
87. Coscinodiscus Rothii (Ehr.) Grun.
88. Coscinodiscus subtilis Ehr.
89. Coscinodiscus Woodwardii Eul.
90. Coscinodiscus Woodwardii Eul. var.
91. Cyclotella striata (Kütz.) Grun.
92. Cymatopleura elliptica (Breb.) W. S.
93. Cymatosira Lorenziana Grun.
94. Datoma tenue Ag. var. elongata Lyngb.
95. Dictyoneis marginata (Lewis) Cl. = Navicula marginata Lewis
96. Dimmeragramma minus (Greg.) Ralfs
97. Diploneis excentrica Boyer
98. Ditylum Brightwellii (West) Grun.
99. Donkinia carinata (Donk.) Ralfs
100. Eucampia Zodiacus Ehr.
101. Eunotia major (W. S.) Rab.
102. Eunotogramma laevis Grun.
103. Eupodiscus radiatus Bail.
104. Grammatophora macilenta W. S. var. subtilis Grun.
105. Hantzschia Amphioxys Grun
106. Hemiaulus Heibergii Cl.
107. Huttonia Reichardtii Grun.
108. Hyalodiscus stelliger Bail.
109. Hyalodiscus subtilis Bail.
110. Licmophora Ehrenbergii (Kütz.) Grun.
111. Licmophora Ehrenbergii (Kütz.) Grun. var. ovata (W. S.) Grun.
112. Licmophora Ehrenbergii (Kütz.) Grun. var. angustata Grun.
113. Lithodesmium undulatum Ehr.

114. Mastogloia elegans Lewis var.
115. Mastogloia Grunovii A. S.
116. Mastogloia Jelineckiana Grun.
117. Melosira concentrica A. S.
118. Melosira sulcata (Ehr.) Kütz.
119. Melosira lyrata Grun. var.
120. Navicula abrupta (Greg.) Donk. var.
121. Navicula Adrena A. S.
122. Navicula aestiva Donk.
123. Navicula approximata Grev. var.
124. Navicula aspera Ehr.
125. Navicula bombus (Ehr.) Kütz.
126. Navicula Brasiliensis Grun.
127. Navicula Brasiliensis Grun. var. bicuneata Cl.
128. Navicula cancellata Donk.
129. Navicula concilians? Cl.
130. Navicula crabo (Ehr.) Kütz.
131. Navicula cruciformis Donk.
132. Navicula digito-radiata (Greg.) Ralfs
133. Navicula flexuosa Cl.
134. Navicula forcipata Grev.
135. Navicula forcipata Grev. var. nummularia Grev.
136. Navicula formosa Greg.
137. Navicula Hennedyi W. S.
138. Navicula irrorata Grev. var.?
139. Navicula lata (Breb.) W. S.
140. Navicula liber W. S.
141. Navicula lyra Ehr. var.
142. Navicula maculata (Bail.) Cl.
143. Navicula major Kütz.
144. Navicula marginata Lewis
145. Navicula nobilis (Ehr.) Kütz.
146. Navicula nobilis (Ehr.) Kütz. var. Dactylus (Ehr.) V. H.
147. Navicula Palpebralis Breb.
148. Navicula peregrina (Ehr.?) Kütz.
149. Navicula permagna (Bail.) Edw.
150. Navicula Powellii Lewis
151. Navicula praetexta Ehr.
152. Navicula Puella A. S.
153. Navicula rectangulata Greg.
154. Navicula retusa Breb.
155. Navicula Smithii Breb.
156. Navicula spectabilis Grev. var. emarginata Cl.
157. Navicula suborbicularis (Greg.) Ralfs
158. Navicula Trevelyana Donk.
159. Navicula n. sp.
160. Nitzschia circumsuta (Bail.) Grun.
161. Nitzschia granulata Grun.

162. Nitzschia longissima (Breb.) Ralfs
163. Nitzschia panduriformis Greg.
164. Nitzschia punctatum W. S.
165. Nitzschia Tryblionella Hant. var.
166. Opephora Schwarzii (Grun.) Petit.
167. Plagiogramma staurophorum (Greg.) Heib.
168. Plagiogramma tesselatum Grev.
169. Plagiogramma Wallichianum Grev.
170. Pleurosigma Balticum (Ehr.) W. S.
171. Pleurosigma delicatulum W. S.
172. Pleurosigma elongatum W. S.
173. Pleurosigma formosum W. S.
174. Pleurosigma Normanii Ralfs
175. Pleurosigma rigidum W. S.
176. Pseudo-Auliscus radiatus (Bail.) Ratt.
177. Rhabdonema Adriaticum Kütz.
178. Rhaphoneis amphiceros Ehr.
179. Rhaphoneis Belgica Grun. (monstrosity)
180. Rhizosolenia acuminata H. Perag.
181. Rhizosolenia alata Brightw.
182. Rhizosolenia alata Brightw. forma corpulenta
183. Rhizosolenia calcar-avis Schultze
184. Rhizosolenia imbricata Brightw.
185. Rhizosolenia robusta Norm.
186. Rhizosolenia setigera Brightw.
187. Rhizosolenia n. sp.
188. Rhizosolenia n. sp.
189. Rhoicosphenia curvata (Kütz.) Grun.
190. Roperia tesselata Grun.
191. Scoliopleura latestriata (Breb.) Grun.
192. Scoliopleura tumida (Breb.) Rab.
193. Stephanopyxis corona (Ehr.) Grun.
194. Stephanopyxis Palmeriana (Grev.) Grun.
195. Stephanopyxis turris (Grev.) Ralfs var. inermis Grun.
196. Surirella fastuosa Ehr.
197. Surirella Febigerii Lewis
198. Surirella gemma Ehr.
199. Surirella striatula Turp.
200. Thalassiosira decipiens (Grun.) Jörg.
201. Thalassiothrix Frauenfeldii (Grun.) Cl. + Grun.
202. Terpsinoe Americana (Bail.) Ralfs
203. Trigonium alternans (Bail.) Mann
204. Trigonium hyalinum (Grev.) Conger
205. Tropidoneis lepidoptera (Greg.) Cl.
206. Tropidoneis seriata Cl.

Genera = 54
Species = 206

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THE EFFECT OF NITRATE FERTILIZER ON STOMATAL BEHAVIOR

By ANNE L. PLEASANTS

INTRODUCTION

Of all the elements commonly considered as essential plant food, nitrogen, according to Allison (1), stands out in many ways as the most important. Its effect upon the growth of plants is perhaps greater than that of any of the other elements (18). Not only is it deficient in many soils, but it plays an exceedingly important part in plant metabolism, including both constructive changes and also the respiratory reactions resulting in the destruction of carbohydrates and proteins (1).

That there is a relation between the nitrogen supply and the water requirement of a plant is shown by the review of literature on the water requirement of plants by Briggs and Shantz (2). In this review the following investigators are cited as having found either a slight or a marked reduction in the water requirement of plants according to the use of nitrogen: Von Seelhorst found a marked reduction accompanied the use of nitrogen both alone and in combination. Wilfarth and Wimmer found that as a rule nitrogen lowered the water requirement of each crop considered, and Ohmer, working with squarehead wheat, also found a reduction in the water requirement with the use of nitrogen. Kiesselback (8) gives evidence that the water requirement is lessened in soils to which nitrogen fertilizers are added.

In regard to the effect of stomatal movement on the rate of water loss by transpiration, Loftfield (11) with potted plants in heavily watered and dry soils shows that the stomata regulated the water loss from plants. The same investigator (11) working out of doors found that when the environmental factors did not change too rapidly through the day, transpiration and stomatal apertures varied alike (15), and if water is deficient the stomata close much earlier in the day than if it is plentiful. Sayre (14) points out that the exchange of gases and loss of water from leaves occur mainly through the stomata. Lloyd (9), with the use of potometers, found that the stomata might continue to open while the rate of transpiration was decreasing or the opposite

might be true. Scarth (15) in a review of stomatal movement says, the general conclusion is, therefore, that the stomata must regulate the rate of transpiration at all apertures if there be a slight wind and only at narrow apertures in most indoor experiments.

Since the water requirement of a plant seems to be decreased by the use of nitrogenous fertilizers (2) and the stomata are supposed to regulate the loss of water by transpiration (11), (15) this work was undertaken to determine the effect of nitrogen in the nutrient medium on stomatal behavior.

METHOD AND MATERIALS

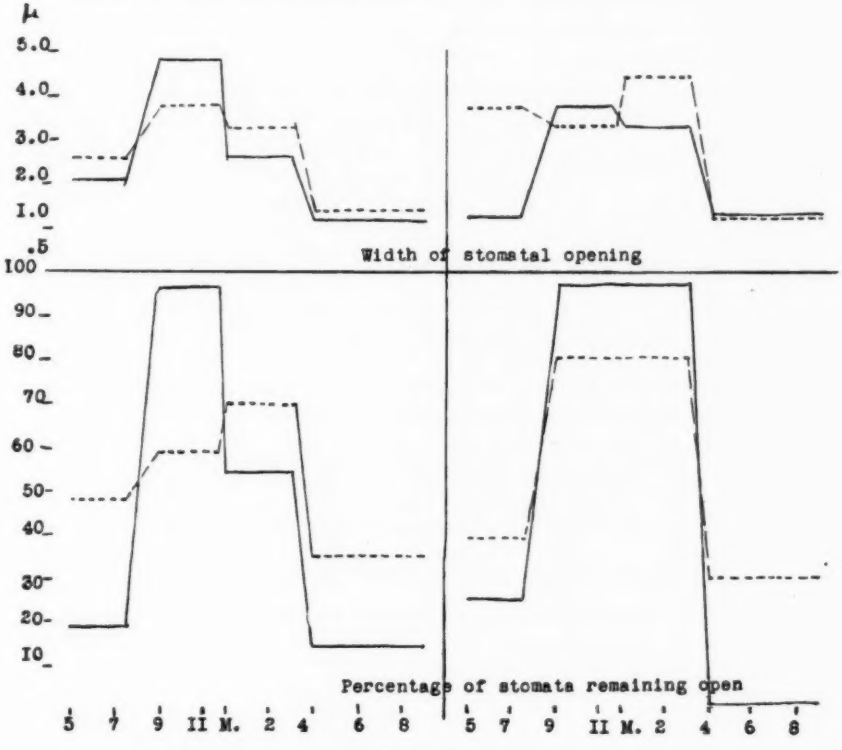
Two species of legumes, *Pisum sativum* and *Phaseolus vulgaris,* vars. Burpee Green Pod and Red Valentine, and *Raphanus sativus* have been used for this work. *Phaseolus vulgaris,* var. Burpee Green Pod, however is the only one which has been used in all of the experiments.

The conditions and nutrient media in which the plants have been grown for examination are as follows:

I. Plants grown indoors in Knop's nutrient solution.

Phaseolus vulgaris, Burpee Green Pod and Red Valentine, and *Pisum sativum* were grown in the laboratory, with south and east exposure, from Feb. to June, 1929. Two nutrient media were used: (a) water cultures contained in pint fruit jars covered with black paper and (b) builders sand, previously leeched and autoclaved at fifteen pound pressure for one and a half hours, and contained in white clay flower pots of approximately four kilogram capacity. Duplicate series of each were supplied with a slightly modified Knop's nutrient solution containing nitrogen: 1.00 gram $Ca(No_3)_2 \cdot 4H_2O$; 0.25 grams $MgSo_4 \cdot 7H_2O$; 0.25 gram KH_2Po_4; and 0.04 $FeCl_3$ in one liter of distilled water. The other series was supplied with the same nutrient solution modified without the nitrogen. $CaCl_2 \cdot 6H_2O$ in the proportion of 0.9 grams per 250 c.c. of water was substituted for the $Ca(No_3)_2$ (4). Changes in the water cultures were made every two to three days and distilled water added between changes to keep the amount constant. The sand cultures were watered with the nutrient solution every two to three days and with distilled water on days when this was not used. One half of each group of plants was kept on tables facing east windows and the other facing south windows. Those facing the south received direct illumination, during clear weather, from ten-thirty or eleven until three

in the afternoon. Those facing the east were illuminated from approximately seven to eleven thirty A.M.

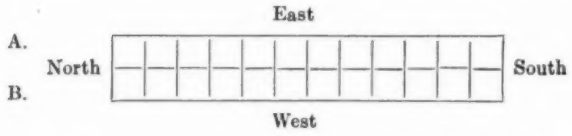


GRAPH 1

——— Grown with fertilizer.
---------- Grown without fertilizer.

II. Plants grown out of doors.

On June 25, 1929, seeds of *Phaseolus vulgaris* var. Burpee Green Pod and *Raphanus sativus* were planted in light clay loam soil in Cincinnati, Ohio. In preparing the soil for planting a three inch sod was removed from a plot 6′ by 8′. After thoroughly pulverizing the soil a 10″ board was sunk through the median length of the plot dividing it into halves;



At the time of planting sodium nitrate in the ratio of one hundred and seventy five pounds to the acre was applied to section B of the plot. Section A received no fertilizer. A disadvantage in the location of the plot was the shading caused by trees from a hundred to two hundred feet away which prevented direct sunshine before eight-thirty in the morning and after three in the afternoon. However the two halves were apparently equally illuminated.

III. Plants grown in soil with controlled moisture content of 20 and 50 per cent of the water holding capacity.

Plants of *Phaseolus vulgaris*, Burpee Green Pod, were grown in soil with moisture content and soil modified as follows:

Soil A. Medium dark sandy loam soil and builders sand mixed half and half. The water holding capacity of this modified soil was 25 per cent. Two groups of this were used:

Group I. With moisture content 50 per cent of the water holding capacity.

Group II. With moisture content 20 per cent of the water holding capacity.

Soil B. The medium dark sandy loam soil not mixed with sand. The water holding capacity 30 per cent.

Sodium nitrate in the ratio of one hundred parts to one million dry weight of soil was applied to one series of each group of soil A and B. A similar series of each group, except soil B, was used without the nitrate.

The soil for that part of the experiment to which no nitrate was added was previously autoclaved for two hours at fifteen pounds pressure in order to destroy nitrogen fixing bacteria. The pH value as determined at the beginning of the experiment was 7.2.

The method used for setting up the experiment was that used and described by Reed (14). This consisted of placing the soil previously mixed with water and the solution of sodium nitrate, in the desired proportions, in wire baskets and sealing with paraffin. The advantage of this method is that the roots of the plants grow more equally dis-

tributed through the soil and not massed at the bottom of the container as they often do when grown in pots.

Seeds of *Phaseolus vulgaris*, Burpee Green Pod, were germinated in moist chambers until the radicles were approximately 2 to 3 centimeters long. The seedlings were then placed with the radicles in holes made through the paraffin equal distances from the center of the basket. Moist cotton was kept over the seedlings until they took root. The water content was kept constant by the daily addition of sufficient tap water through a glass tube, in the center of the top of the basket, to restore the original weight.

In this part of the experiment the plants were grown in the laboratory, as already described, from February to the last of April 1930. The plants were placed on tables which were moved from south to east windows so that all of the plants were illuminated so far as possible for the same length of time each day. During clear weather they were in the sunshine from seven-thirty in the morning to three in the afternoon.

The method used for the study of the size of the stomata of the leaf was the absolute alcohol method introduced by Lloyd (9) and used by Loftfield (11) and Eckerson (7). Stomata examined by this method and checked by direct observations of stomata in position on the uninjured leaf were found by Loftfield (11) to agree very closely. Sayre (15) indicates that caution must be used in the alcohol method as removing the stomata may change the size of the pores. However, because of the size of the openings of the stomata of the plants studied, and the greater convenience offered for the examination of material the alcohol method seemed to offer advantages over the direct method for this work.

Material collected for examination was stripped from the same position, so far as possible, from mature leaves of three different plants at stated intervals of time. The epidermis was removed from near the base of the leaf between the midrib and the first large vein.

In studying this material, examination was made from two fields of the microscope, of the width of the aperture, the percentage of stomata closed and the number per unit area, for each plant stripped, at the hourly interval each day when collections were made. Averages were then obtained for the hourly intervals for all dates given. Since the collections were begun shortly after the leaves matured and continued until after fruiting these data represent the condition of the stomata, more or less, throughout the life of the plant.

Since the measurements made of the length of the stomatal pores did not indicate that those grown with and without the addition of

nitrogen differed greatly, the width of the opening has been given as representing the difference in the two series, for Sayre (15) has pointed out that this is the best means of expressing the degree of opening of the stomata. Also because of the scarcity of the stomata on the upper leaf surface and because of the apparent correlation of those present with those of the lower surface, all data given are representative of the lower surface.

RESULTS

No consistent difference has been noted in the number of stomata per unit area for those grown with and without the addition of the nitrogen to the nutrient media.

While the stomata of the plants grown in the Knop's nutrient solution without the nitrogen were slightly shorter than those grown in the same nutrient solution with the nitrogen, no consistent difference has been noted in the length of those grown in the soil to which the nitrate was or was not added.

Because of the presence of very few nodules, the nitrogen supply has, apparently, been modified very little by the action of nitrogen fixing bacteria, for any of the plants studied.

I. Plants grown indoors in Knop's nutrient solution.

In this somewhat preliminary part of the work no data were obtained when the plants were not directly illuminated. Also it may be suggested that since the data from nine until eleven are from plants illuminated from the east windows from seven to eleven-thirty, and that given from twelve to two-thirty from the plants grown in front of the south windows and illuminated from eleven to about three, the data from twelve to three might be modified if the plants had been in the sunshine during the forenoon. However, it agrees with that of the forenoon in indicating that the nitrogen has influenced the stomata to open wider and for fewer of them to remain closed when the plants are in the sunshine.

The material from which the data for these plants were obtained was collected on March 21, 27, 28, April 2, 1929. Camera lucida drawings are given for those made on April 2. Averages of the data are given in table I.

Pots of both varieties of *Phaseolus vulgaris* were sealed on April 21, 1929, with warm paraffin. The weight at the beginning and at the

TABLE I

The data represent the percentage of stomata closed and the average width in microns, at the stated intervals for the plants grown indoors in Knop's nutrient solution, from the time of mature leaf formation until after fruiting. Material for examination was collected March 21, 27, 28 and April 2, 1929.

TIME	PHASEOLUS VULGARIS, VAR. RED VALENTINE—GROWN IN KNOPS' NUTRIENT SOLUTION							
	Sand cultures				Water cultures			
	Nitrogen		No nitrogen		Nitrogen		No nitrogen	
	Per cent closed	Width	Per cent closed	Width	Per cent closed	Width	Per cent closed	Width
Material from plants at east windows:								
9:00 a.m.	14	1.9	46	1.6	23	1.8	67	1.8
9:30 a.m.					15	2.5	40	1.4
10:00 a.m.	13	2.2	33	1.8	52	2.2	56	1.8
11:00 a.m.	18	1.7	61	1.3	21	2.0	62	1.2
11:30 a.m.	61	1.1	80	1.6	11	3.3	30	1.9
Material from plants at south windows:								
12:00 m.	69	1.2	46	1.6	37	2.0	63	1.3
12:30 p.m.	30	1.8	43	2.0	8	2.8	13	2.1
1:30 p.m.	6	2.0	39	1.4	16	1.3	63	1.1
2:30 p.m.	8	1.5	78	1.6	60	1.6	78	2.0
Averages of the above data 9:00 a.m. to 2:30 p.m.	38	1.8	53	1.4	11	2.2	55	1.5
	PISUM SATIVUM—GROWN IN KNOP'S NUTRIENT SOLUTION; WATER CULTURES				PHASEOLUS VULGARIS-BURPEE—KNOP'S NUTRIENT SOLUTION; SAND CULTURES			
Material from plants at east windows:								
9:00 a.m.	16	1.5	30	1.2	23	2.0	67	1.3
9:30 a.m.					40	1.9	90	1.3
10:00 a.m.	1	2.8	23	1.4	21	1.5	51	1.1
11:00 a.m.	9	1.8	71	0.9	0	2.4	0	1.4
11:30 a.m.					30	2.0	53	1.4
Material from plants at south windows:								
12:00 m.	0	2.8	76	1.0	30	2.2	65	1.2
12:30 p.m.					0	2.4	50	1.7
1:30 p.m.					9	2.3	15	2.1
2:30 p.m.					18	2.2	60	1.2
Averages—9:00 to 2:30	8	2.2	47	1.1	19	2.1	50	1.4

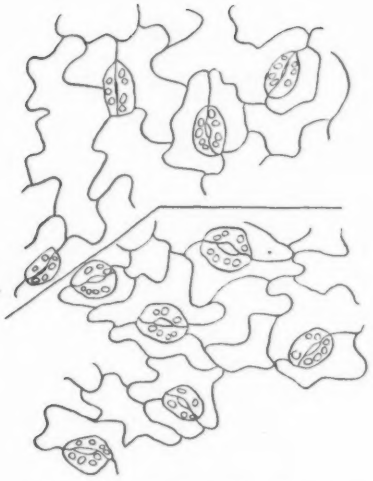


FIG. 1. CAMERA LUCIDA DRAWINGS OF STOMATA OF PHASEOLUS VULGARIS-BURPEE, AT 10 A.M.

Those above the line were from plants grown with Knop's nutrient solution modified without nitrogen and only 5 per cent were open. Below the line are these grown with nitrogen and 92 per cent were open.

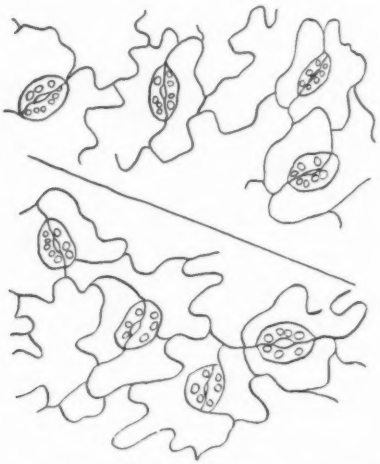


FIG. 2. CAMERA LUCIDA DRAWINGS OF STOMATA OF PHASEOLUS VULGARIS-BURPEE AT 11 A.M. WHEN GROWN IN SAND WITH KNOP'S NUTRIENT SOLUTION MODIFIED WITH (BELOW) AND WITHOUT (ABOVE) NITROGEN

At this time 90 per cent of those grown without this element were closed, while 33 per cent of those grown with it were not functional.

end of the experiment was obtained and the water loss computed. After obtaining the leaf surface and dry weight of the plants, the water loss per gram of dry weight and per square centimeter of leaf surface was obtained. The results showed that both species of plants which had been grown in the nutrient solutions with the nitrogen lost less water both per square centimeter of leaf surface and also per gram of dry weight than did those grown without this material. Since similar

FIG. 3. CAMERA LUCIDA DRAWINGS OF STOMATA OF PHASOLUS VULGARIS-BURPEE, AT 12 M.

Those above the line were grown without nitrogen, and 62 per cent of the stomata were closed at this time. Below the line shows the stomata of the plants grown with nitrogen, and only 30 per cent were closed.

results are shown by the data given for the plants grown in the sealed wire baskets in part III of the experiment the data for this part of the work have not been given.

II. Plants grown out of doors in soil with and without the addition of sodium nitrate.

The conditions under which the plants were grown for this part of the work have already been described.

As for the differences in the plants grown in the fertilized and non-fertilized plots, the fertilized plants of *Phaseolus vulgaris* were considerably larger than those not so treated. But while the fertilized plants of *Raphanus sativus* were larger the difference in size was not so noticeable. Less difference in the size of the leaves of both species was apparent. However the fertilized one usually produced more of them.

There was a very evident difference observed in the stomatal movement of both species of plants receiving the sodium nitrate, in contrast to those that were grown in the plot to which no fertilizer was added. Although daily variations were observed in the stomatal movement of the fertilized plants as compared to similar plants on different days, there were also consistent daily differences between them and the unfertilized ones. Since the two series were grown under apparently identical conditions of moisture, temperature, and light, these differences in the stomatal movement seem to be due to the difference in the nitrogen content of the soil.

The leaves of the plants of both species receiving the nitrate were found to maintain a larger percentage of closed stomata, and those that were open averaged smaller openings, from the beginning of day light until directly illuminated, than the same species when grown without the addition of this fertilizer. This nutrient material, also seemed to make the stomata, which had remained closed more successfully before direct illumination, open faster and to a greater width when in direct sunshine, than did the stomata of the other plants. The stomata of the non-fertilized plants were often smaller just after being directly illuminated than they were during the period of diffused light. Also the fertilized plants had often begun a mid-day closure before the others had reached their maximum size. And although the plants from the fertilized plot averaged more stomata open and with wider openings for the entire period of sunshine, the openings were usually smaller and more of them were closed in the early afternoon. Just as the stomata of the plants grown on the fertilized plot, seemed to open more suddenly in direct light, so they also seemed to close more rapidly after the sun had left the plants in the afternoon.

Another difference noted between the two series of plants was that, although the stomata of those not fertilized were larger in the early afternoon during continuous clear weather, on clear days following cloudy weather, they maintained smaller stomata during both afternoon and forenoon than did the fertilized plants.

The data were obtained from the material collected at hourly inter-

TABLE II

DATA GIVING THE PERCENTAGE OF STOMATA REMAINING CLOSED AND THE AVERAGE WIDTH IN MICRONS OF THOSE OPEN FROM THE TIME OF MATURE LEAF FORMATION UNTIL AFTER FRUITING, OF THE PLANTS GROWN OUT OF DOORS

These data indicate that both species of plants when grown with the addition of nitrogen to the soil maintain a greater number of stomata open and with larger openings, when in the sunshine than did those not fertilized. In diffused light this was reversed. Collection of material was made July 5, 8, 23, 25 and August 13, 1929.

TIME	PHASEOLUS VULGARIS–DURFEE GREEN POD				RAPHANUS SATIVUS			
	Nitrate added to the soil		Nitrate not added		Nitrate added to soil		Nitrate not added	
	Per cent closed	Width	Per cent closed	Width	Per cent closed	Width	Per cent closed	Width
Diffused light:								
5:00 a.m.	90	2.3	48	2.7	90	2.0	88	1.3
5:30 a.m.	96	1.7	88	1.7				
6:00 a.m.	73	2.0	44	1.1	100	0.0	88	1.5
7:00 a.m.	78	2.7	42	3.5	34	1.6	6	1.6
7:30 a.m.	66	1.6	37	1.5				
8:00 a.m.	10	2.9	58	4.4				
Direct:								
9:00 a.m.	12	4.5	36	2.8	34	2.0	00	0.0
10:00 a.m.	7	4.4	57	2.8	4	5.6	27	3.1
11:00 a.m.	0	5.4	25	3.9	0	3.5	33	2.8
12:00 m.	52	3.0	32	4.0	0	3.0	17	3.0
12:30 p.m.	25	4.1	15	2.9				
1:00 p.m.	28	1.8	9	3.9	5	4.3	00	5.6
1:30 p.m.	21	2.0	33	4.6				
2:00 p.m.	58	2.6	52	3.0	6	2.8	23	3.3
3:00 p.m.	59	2.8	40	2.6	0	3.2	00	6.0
Diffused light:								
4:00 p.m.	78	2.0	75	1.3	64	1.7	50	2.3
5:00 p.m.	88	1.7	59	1.5	98	0.8	89	0.8
6:00 p.m.	77	1.1	45	2.3	93	1.6	65	1.5
6:30 p.m.	91	1.5	84	1.5				
7:00 p.m.	78	1.4	65	1.5	93	1.3	83	1.0
8:00 p.m.	95	0.9	85	1.1	85	0.9	80	1.1
9:00 p.m.	99	0.4	88	0.9	98	0.3	96	0.3
Averages:								
5:00– 7:30 a.m.	81	2.0	52	2.5	75	1.2	39	3.7
9:00–11:30 a.m.	4	4.8	41	3.8	03	3.7	20	3.2
12:00– 3:00 p.m.	46	2.6	30	3.3	03	3.3	20	4.4
9:00 a.m.–3:00 p.m.	25	3.7	55	3.5	08	3.8	20	3.8
4:00– 9:00 p.m.	86	1.1	65	1.3	99	1.4	71	1.4
5:00–7:00 a.m.–4:00–9:00 p.m.	87	1.6	60	1.9	83	1.3	55	2.5

vals, on clear days of bright sunshine, July 5, 8, 23, 25, and August 13, 1929. Measurements were made and recorded for each of these dates, and averages computed for all. Also averages of the width of the stomata and the percentage remaining closed have been given for the time before the plants were directly illuminated; while they were in direct sunshine; and after the sun had left them. These results are given in table II.

III. Plants grown indoors in soil having a controlled water content of 20 and 50 per cent of the water holding capacity.

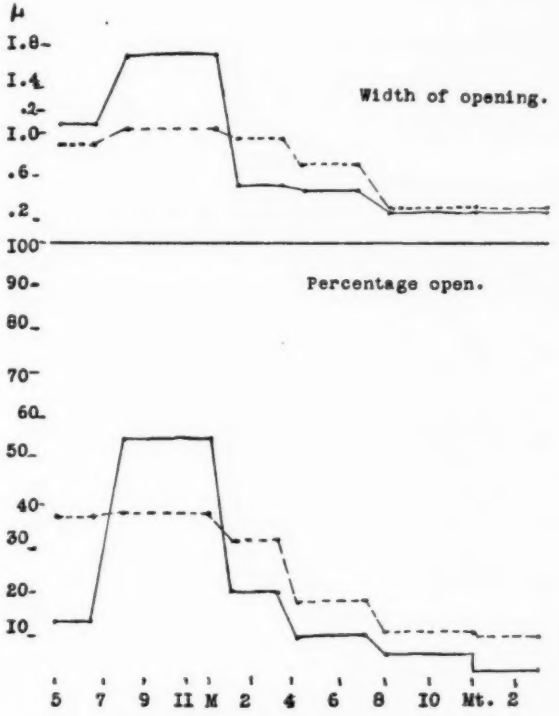
The plants grown in the wire baskets in this part of the experiment remained in very good condition, apparently, throughout the period of examination. The largest were those grown in the 50 per cent moisture and nitrogen. There was, however, not a very noticeable difference between them and those of the same series grown without the nitrogen. The fertilized plants had more leaves than those not fertilized. The greatest contrast in size was found between those grown with 20 per cent moisture content. Those of this series without the nitrate were the smallest. Both the plants and the leaves of these were small.

The observations of this part of the work as contrasted with the other two experiments, gave evidence of considerable variations in the stomata of the same species of plant when grown under different environmental conditions. While the stomata of Burpee Green Pod were largest when grown out of doors, and fewer of them remained closed during the period of sunshine, this species when grown in the wire baskets had the smallest stomata and more remained closed than they did in any other part of the work. These differences may in part be due to differences in temperature, humidity, and degree of illumination. The more poorly developed root system of those in the sealed baskets may also be responsible for some of the variations. The pH value of the soil as tested at the end of the experiment was approximately the same as found at the beginning.

However, practically the same results, so far as what seemed to be the effect of nitrogen on the stomata is concerned, were observed from this study as in the first two series of experiments.

The stomata of all of the plants grown with the nitrogen added to the soil, as compared to the duplicate series without the nitrogen, were found to be larger and more of them were open during forenoon when in direct sunlight. Also they were usually smaller during the early after-

noon. When not directly illuminated they seemed to close more quickly and to remain closed more completely than the other series did. This difference was not as evident during early morning as it seemed to be when the plants were grown out of doors. One reason might be because fewer collections of material were made just before sunrise.

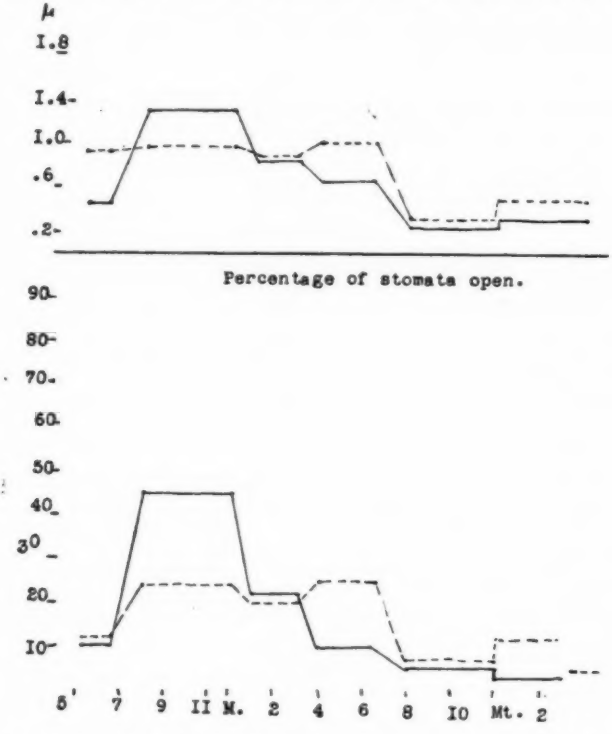


GRAPH 2. PHASEOLUS VULGARIS-BURPEE. GROWN IN SOIL A WITH 50 PER CENT MOISTURE

——— Grown with fertilizer.
——— Grown without fertilizer.

The plants grown with the limited water supply and the addition of nitrogen differed from those of the same series grown without the fertilizer in keeping more of the stomata closed, especially during the

afternoon. The stomata of the former during forenoon were only slightly smaller than those of the plants grown with the maximum water supply. Those grown in the soil B-dark sandy loam—to which was added nitrogen, showed the widest opening in the morning with the



GRAPH 3. PHASEOLUS VULGARIS-BURPEE GREEN POD GROWN IN SOIL A WITH 20 PER CENT MOISTURE. WIDTH OF STOMATAL OPENING

---------- From plants not fertilized.
———— From plants with fertilizer.

smallest in the afternoon of any of the plants grown in the 20 per cent moisture content. They also had more stomata closed, especially in the afternoon.

During cloudy weather the plants grown without the addition of the sodium nitrate maintained the widest stomatal aperture with more

TABLE III

The table gives averages of data, obtained during clear weather, from the plants grown in soil with controlled moisture content. During the forenoon the nitrated plants had more stomata open and the apertures were wider. The same plants had fewer functional stomata in the afternoon, especially in the soil with low moisture content. Material collected for examination February 27, March 2, 12, 20, and April 5, 1930.

TIME	PHASEOLUS VULGARIS-BURPEE GREEN POD									
	Grown in soil A								Grown in soil B	
	With 50 per cent moisture				With 20 per cent moisture				With 20 per cent moisture	
	Nitrate added		Nitrate not added		Nitrate added		Nitrate not added		Nitrate added	
	Closed	Width	Closed	Width	Closed	Width	Closed	Width	Closed	Width
5:30 a.m.	97	1.0	54	0.5	95	0.4	88	0.4	92	0.3
6:30 a.m.	78	1.3	72	1.3	86	0.6	86	0.6	84	0.6
7:30 a.m.	80	1.6	86	0.6	63	1.6	73	1.6	60	1.6
8:00 a.m.	49	1.5	67	1.1	55	1.2	60	0.8	78	1.4
8:30 a.m.	44	1.7	61	1.2	55	1.1	74	1.0	41	1.5
9:00 a.m.	52	1.7	65	1.3	53	1.4	75	0.7	77	1.4
9:30 a.m.	27	2.1	56	1.0	35	1.0	58	0.8	69	1.2
10:00 a.m.	47	1.6	59	1.1	60	1.2	70	0.8	46	1.4
11:00 a.m.	42	1.6	48	1.0	52	1.6	60	1.0	62	1.3
12:00 m	55	1.5	81	0.9	79	1.2	55	1.8	68	1.7
1:00 p.m.	87	0.6	68	0.9	79	0.7	72	0.6	89	0.7
2:00 p.m.	90	0.4	62	1.1	78	0.8	86	1.2	99	0.3
3:00 p.m.	72	1.1	75	1.0	77	1.0	74	1.0	85	0.5
4:00 p.m.	85	1.0	79	1.2	92	0.9	67	0.9	90	0.4
4:30 p.m.	60	0.7	75	0.5	95	0.5	63	0.8	95	0.5
5:00 p.m.	93	0.2	76	1.0	92	0.4	91	0.4	90	0.6
6:00 p.m.	100	0.0	94	1.0	71	1.0	98	1.0	98	0.6
6:30 p.m.	99	0.5	98	0.3	96	0.4	85	0.9	88	0.6
8:15 p.m.	90	0.3	89	0.4	91	0.3	91	0.3	94	0.3
9:15 p.m.	93	0.4	88	0.2	90	0.3	90	0.3	98	0.3
10:00 p.m.	90	0.2	95	0.5	100	0.0	98	0.3	99	0.2
12:00 midnight	90	0.3	85	0.4	99	0.3	97	0.3	99	0.2
3:30 a.m.	98	0.3	90	0.4	97	0.3	88	0.5	99	0.3
Averages										
5:30–6:30	87	1.1	63	0.5	90	0.4	88	0.9	88	0.4
8:00 a.m.–12:00 m.	45	1.7	62	1.0	55	1.3	76	1.0	63	1.4
1:00–3:00 p.m.	80	0.5	68	1.0	78	0.8	80	0.9	91	0.5
4:00–6:30 p.m.	90	0.5	82	0.7	88	0.6	75	1.0	90	0.5
8:15–12:00 midnight	94	0.3	89	0.3	95	0.3	93	0.4	98	0.3

of them open than did the fertilized plants. This difference was more evident for those grown with the low water content. On the other hand

TABLE IV

DATA GIVING THE CONDITION OF THE STOMATA OF THE PLANTS GROWN WITH 20 AND 50 PER CENT MOISTURE, AND WITH AND WITHOUT THE ADDITION OF NITRATE, DURING CLOUDY WEATHER, FROM THE TIME OF MATURE LEAF FORMATION UNTIL AFTER FRUITING

Material collected for examination February 28, March 7, 18, 27, and April 8, 1930.

TIME	PHASEOLUS VULGARIS–BURPEE GREEN POD									
	Soil A								Soil B	
	With 50 per cent moisture				With 20 per cent moisture				With 20 per cent moisture	
	Nitrate added		Nitrate not added		Nitrate added		Nitrate not added		Nitrate added	
	Closed	Width	Closed	Width	Closed	Width	Closed	Width	Closed	Width
5:00 a.m.	92	0.3	95	0.7	96	0.7	82	0.4	90	0.4
6:30 a.m.	97	0.5	98	0.3	88	0.3	90	0.3	90	0.4
7:00 a.m.	90	0.8	80	0.4	80	0.3	92	0.3	91	0.4
8:00 a.m.	78	0.6	65	1.0	84	0.6	61	0.9	80	0.8
9:30 a.m.	80	0.5	74	1.8	85	0.4	52	0.3	90	0.4
10:00 a.m.	90	0.8	56	0.3	72	0.6	56	0.6	87	0.7
10:30 a.m.	94	0.5	96	0.4	95	0.4	64	0.2	97	0.5
12:00 m.	75	1.7	86	1.0	79	0.9	88	0.7	80	0.9
1:30 p.m.	81	0.9	69	0.9	85	0.6	45	0.8	80	0.5
3:00 p.m.	77	0.6	74	0.6	89	0.4	32	1.6	75	0.8
4:15 p.m.	76	0.6	87	0.7	90	0.8	91	1.0	94	0.7
6:15 p.m.	95	0.3	89	0.5	97	0.7	93	0.3	95	0.3
7:15 p.m.	92	0.4	96	0.5	98	0.6	98	0.6	96	0.3
8:15 p.m.	90	0.3	89	0.4	91	0.3	93	0.3	94	0.3
9:15 p.m.	93	0.4	88	0.2	90	0.3	90	0.3	92	0.3
10:00 p.m.	90	0.2	95	0.5	100	0.0	98	0.3	99	0.3
12:00 midnight	99	0.3	85	0.4	99	0.3	97	0.3	99	0.2
Averages:										
5:00 a.m.–12:00 midnight...	88	0.6	84	0.6	85	0.5	78	0.7	89	0.5
8:00 a.m.–6:00 p.m.....	83	0.7	76	0.8	89	0.6	65	0.7	85	0.6

both groups of plants grown with the limited water supply and with nitrogen added kept more stomata closed and those that opened had smaller openings than those grown with the nitrate but with the higher

percentage of moisture. Table III gives the data obtained during the period of sunshine, and table IV during cloudy weather.

The water loss from the plants grown in the sealed wire baskets was recorded daily from February 26 to March 28, 1930, just before the addition of water necessary to maintain a constant weight. A record was made of the loss during certain clear and cloudy days. The loss has

TABLE V

DATA GIVING THE AMOUNT OF WATER LOST PER GRAM DRY WEIGHT, AND PER SQUARE CENTIMETER OF LEAF SURFACE, BY THE PLANTS GROWN IN THE WIRE BASKETS SEALED WITH PARAFFIN

	PHASEOLUS VULGARIS-BURPEE GREEN POD				
	Grown in soil A				Grown in soil B
	50 per cent moisture		20 per cent moisture		20 per cent moisture
	Nitrate added	No nitrate added	Nitrate added	No nitrate added	Nitrate added
Total water loss 2/26 to 3/28	3947.2	3920.0	2387.0	1596.0	2130.9
Water loss for five 24-hour periods—clear days	726.5	680.6	497.5	341.8	425.5
Water loss for two 24-hour periods—cloudy days	134.1	138.5	101.1	94.4	117.0
Dry weight of the plants	20.6	17.24	13.35	7.33	14.95
Leaf surface in square cm	9026.0	3678.0	5038.0	1198.0	6012.0
Total water loss for 1 sq. cm. of leaf surface	00.44	1.06	00.47	1.33	00.34
Total water loss 1 gram dry weight	191.60	227.37	178.82	217.20	143.70
Water loss per sq. cm. leaf surface during clear period	0.08	0.18	0.09	0.29	0.07
Water loss per sq. cm. of leaf surface during the cloudy period	0.015	0.038	0.020	0.079	0.019

been computed for the square centimeter of leaf surface and per gram of dry weight. The results confirm those of Experiment I. The fertilized plants lost less water per gram of dry weight and also per centimeter of leaf surface than did those not fertilized. The plants which lost less per gram of leaf surface were those grown in the better grade of soil (B) with 20 per cent moisture and nitrate. The plants grown in soil A with 20 per cent moisture and no nitrate apparently required three times as much water as the duplicate series with the nitrate, and

only slightly less than four times as much as those grown with a similar moisture content in soil B with the nitrate added. During cloudy weather approximately twice as much water was lost by the plants grown without the addition of nitrogen as with it.

Comparisons of the leaf surface produced by these plants give interesting differences. All of the fertilized plants produced more than those not fertilized. More than one and a half times as much was produced by those grown in the better grade soil B, fertilized and grown with only 20 per cent moisture, as was produced by those grown in soil A with 50 per cent moisture without the nitrate. Those in soil A grown with 50 per cent moisture and with fertilizer, produced more than two and a half times as much as those grown under similar conditions but without the nitrate. The fertilized plants in soil A and 20 per cent moisture developed a leaf surface more than four times as extensive as those in the same soil and moisture content but with no nitrate added.

DISCUSSION

Published information concerning the influence of nitrogenous fertilizers on stomatal activity seems to be limited. Thus far no reference in literature has been found on the subject. This study indicates that nitrogen does influence these structures physiologically. But the way in which this is brought about is not so clear. If the plastids of the guard cells were similar to those of the leaf mesophyll the interpretation would be more evident. But it has been pointed out that these bodies differ structurally, physiologically, and genetically from the plastids of the mesophyll, and the green color contained by them does not give the micro-chemical test for chlorophyll (15). Also while starch occurs in the guard cells under any conditions, even in plants grown from the seed in complete darkness, starch is found in the chloroplasts only in light and soon disappears in continued darkness (15).

That the characteristic changes in the guard cells are due to fluctuations of the H-ion concentration, has been demonstrated by both Sayre (15) and Scarath (16). Both investigators found the pH value more alkaline when the guard cells were fully open but Scarath indicates that there may also be an "acid" value for the opening. Starch was found to appear in the pH zone of closure and to disappear in that of the opening. The causes suggested for this were the changes in sap colloid produced in pH condition which would initiate the opening, and the activity of enzymes in the acid free medium which would cause changes of starch to sugar and thus change the osmotic value of the cells.

Sayre (15) gives as one of the theories which might be advanced to account for the decrease in acidity of the guard cells (which would lead to their opening) as being the accumulation of CO_2 from respiration which would be used in photosynthesis in sunlight but not in darkness.

That nitrogen may play a part in respiratory reactions has been suggested by Allison (1) and Schertz (18) and Ville suggests that it also bears a relation to chlorophyll. Ville, according to Denber (6), while working with hemp plants found that a great decrease in chlorophyll and carotin was brought about by a deficiency in nitrate. Schertz (18) in working with *Coleus* shows that nitrogen is the element lacking which causes the mottling of leaves, and suggested that either chlorophyll would be prevented from forming or if formed would be decomposed, for in those plants having a low concentration of chlorophyll, this material seems to be decomposed in light, while plants with much chlorophyll show little or no breaking up of the chlorophyll (18).

The relation of chlorophyll to photosynthesis is well known. That CO_2 is one of the limiting factors in the same process has been shown by Blackman (16).

It may be suggested that the effect which nitrogen has seemed to produce in the activity of the stomata of the plants used in this study, may be one of interrelation between the part which Allison and Schertz suggested is played by nitrogen in the respiratory reactions, and chlorophyll formation or prevention of its decomposition. If more chlorophyll is present it is supposed that photosynthesis might take place more rapidly, which would lead to CO_2 being taken out of solution, and so changing the pH value, and thus lead to the wider opening of the stomata. If respiration is influenced by nitrogen to cause more carbohydrates and proteins to be destroyed (1) the acid condition found in those plants grown with its use might be such as to lead to the more complete and continued closure of the stomata, when the plants were not in light sufficient to use the excess CO_2 in photosynthesis.

The greater efficiency in the use of water which the plants with the nitrate fertilizers seem to make in comparison with those grown without this element, may be partially accounted for by less water being lost through transpiration due to the stomata closing more completely when photosynthesis is not taking place. Sayre has pointed out that 50 per cent of the maximum amount could diffuse through the pore when it is only 10 per cent of its maximum size. From that it would seem that considerably more water would be lost by those plants which retained a larger number of open stomata during diffused light as has been found

in this work. Also when in the sunlight, since the fertilized plants maintained the widest open stomata, they would, it is supposed, be using more water due to increased photosynthesis.

SUMMARY

I. Plants used for this study of the effect of nitrate fertilizer on stomata have been grown in duplicate series of sand and water cultures; sandy loam soil with moisture content of 20 and 50 per cent of the water holding capacity; and in light clay loam soil out of doors. One series of each was grown with nitrate added at the time of setting up of the experiment. The other series received no fertilizer.

II. Variations have been noted in the daily march of the stomatal movement from the time of the mature leaf formation until after fruiting of each nitrated series as contrasted with the duplicate series of those not fertilized. These differences are as follows:

A. During clear weather—

1. The stomata of all the fertilized plants have been wider and more of them were open during the forenoon period of direct illumination.
2. During the early afternoon the width of the aperture has been smaller, and more have been closed during the same period.
3. However, during the entire period of direct illumination the stomata of the fertilized plants have averaged a wider aperture and the percentage open has been greater than for those not fertilized.
4. During the period of diffused light, both in early morning and afternoon, the plants grown with addition of nitrate have, with few exceptions, maintained stomata with smaller openings and a larger per centage have remained closed.
5. More stomata remained closed during the period of illumination in both nitrated and non-nitrated plants when grown with low moisture content than when water was not deficient.
6. The stomata of those grown with low water content and nitrogen, opened wider and fewer remained closed during the forenoon than the similar series grown without nitrogen.

7. During the afternoon those fertilized had smaller openings and more remained closed when the water was limited.

B. During cloudy weather:

1. The stomatal apertures of the fertilized plants were smaller and more remained closed.
2. The stomata of the fertilized plants grown in the better grade of soil B, with 20 per cent moisture, maintained the lowest percentage of open stomata, and those open had smallest apertures.
3. Those grown in the soil A with low water content and no nitrate kept more stomata open and the aperture was usually larger than any other of the plants.

III. Concerning water loss.

1. The plants grown with addition of nitrogen have been found to lose less water per square centimeter of leaf surface and per gram of dry weight the twenty-four hour period both during clear and cloudy weather than those not fertilized.
2. Those plants apparently having the lowest water requirement per centimeter of leaf surface and per gram of dry weight were those grown in soil B with the limited water supply and addition of sodium nitrate.

Since nitrogen seems to make the stomata more responsive, opening more quickly and more completely during the period of direct sunshine and closing more quickly and more completely when the plant is not illuminated this may partially account for the lower water requirement, as observed in this work and by other investigators (2).

Grateful acknowledgment is due Dr. Otis F. Curtis of the Botany Department of Cornell for suggesting the problem and for his stimulating interest in the work, and to Dr. L. Edwin Yocum of the Botany Department of North Carolina College for helpful criticism.

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NOTES ON FUNGI, WITH A DESCRIPTION OF A NEW SPECIES OF DITIOLA

By W. C. Coker

Plates 8, 9

Ditiola Shopei n. sp.

Plant peziza-form, 3–8 mm. broad, up to 4 mm. thick; upper surface nearly plane to slightly convex, usually somewhat waved, lower surface convex, abruptly attached to a short, terete, sometimes eccentric stalk about 2 mm. long or less and 1 mm. thick. Stalk insititious, shallowly embedded in the wood with a truncate base; base or nearly the whole length dark. Otherwise color of entire plant orange; hymenium deeper colored. Texture firmly gelatinous, retaining its form and consistency for a long time in water. Flesh translucent, made up of delicate threads, 1.5–3.8μ thick, irregular, much branched and anastomosing; clamp connections often forming very unique long narrow loops. Lower surface made up of peculiar swollen cells with very thick walls and pointed tips. Hymenium confined to the upper surface, about 30–40μ thick. Basidia as usual, prongs about 3.5μ thick and 23–30μ long, with numerous delicate hyphae about 1.5μ thick among them, some of these latter projecting beyond the surface.

Spores curved-elliptic, 4–5 x 14–17.2μ, most of them not divided, but some divided into 2 cells and rarely into 4.

The species seems confined to coniferous wood in the western states, and is different from anything we have seen published. It is distinguished by its very slender, short, abrupt stalk, shallowly inserted with a truncate base, thin, wide cap with large inflated cells on the surface below. The plant we treated in our Notes on Lower Basidiomycetes (Journ. E. M. Sci. Soc. **35**: 178. 1920) as *Ditiola radicata* we now consider *Dacryopsis nuda*, our uncertainty being expressed at the time. This plant common on coniferous wood in North Carolina differs easily in more amorphous shape, much less distinction between cap and stalk, absence of inflated cells below, much more extensive root, and thicker spores. Of the true *Ditiola radicata*, as we now consider it, we have only one specimen (Bresadola, Bellamonte, on *Picea*). The plants are

more peg-shaped than in the present species, are without the inflated cells, and have spores 4–4.5 x 10–13μ.

We take pleasure in naming this species for Prof. Paul F. Shope, who has sent us the type and several other collections.

In our collections the plant most like *Ditiola Shopei* is a delicate and pretty, pale little plant growing on maple wood from Chapel Hill, N. C. (Couch, coll.). So far we have not named this, as the material is not abundant. It has thick-walled cells below, but these are elongated and more cylindrical instead of being short and inflated, and both the plants and spores are smaller.

Colorado. Wild Basin, alt. 7500 ft. On Engelmann spruce, July 14, 1929. Shope, No. 607 (type).
Isabelle Lake. Shope, No. 485.
Long Lake. Shope, No. 603.
Middle Boulder Canyon. Shope and Seaver, No. 2.
Also collection from Colorado by E. Bethel. (N. Y. B. G. Herb., as *Ditiola radicata*, and U. N. C. Herb.).

Lycogalopsis Solmsii

About one year ago we received from Dr. Stevenson of Washington some interesting plants collected in Honduras by Mr. P. C. Standley. One of these turned out to be a very rare species of puffball described from Java by Edouard Fischer in 1886 as *Lycogalopsis Solmsii*. Since that time it has been sent to Lloyd twice from Java (Myc. Notes, pp. 482 and 1244) and so far as we know these are the only recorded collections of it. In his usual peculiar way Lloyd uses a new name *Lycogalopsis subiculosus* for it, but in the same paragraph says it is the same as *L. Solmsii*. He also describes as new another species from Japan. We have not seen this and do not know whether it is a *Lycogalopsis* or not.

Our Honduras collection is the only one ever recorded from the American continent. Fischer thinks that the genus is intermediate between the Hymenogastraceae and the true puffballs. Our plants are larger than Fischer's but as structural details are alike we are calling it that. The plant grows on wood, and forms the fruit body in colonies near together or even touching, as in so many puffballs. Each body begins as a flattish cottony pad of white mycelium, the center of which grows up and enlarges to form the ball. If Lloyd's *subiculosus* is the same, the

plant may at times form a continuous cottony subiculum on which the separate balls are sitting.

Plants subspherical, about 5–7 mm. thick, light clay yellow, nearly glabrous, sessile, opening by irregular tears above, disappearing rather soon except for the disk-shaped basal plate. Peridium 150–200μ thick, simple, clearly defined, with a few short delicate hairs on the surface. Capillitium very peculiar, soon disappearing, consisting of flattened and frayed fascicles of various sizes composed of many very delicate threads, radiating from the base in all directions to the peridium. These apparently are of semi-gelatinous consistency when wet and with poorly defined structure, the distinction between wall and lumen not obvious. The threads quickly dissolve in a weak solution of KOH, leaving behind little granules or rods. Diameter of individual threads on average about 2μ thick, but variable and irregular, very little branched; threads of the cottony pad 1.5–2μ thick, branched, and with obvious clamp connections.

Internal structure remarkable and characteristic, showing concentric rings of growth which are more numerous downward. Gleba almost color of peridium, slightly darker, with many quite irregular, minute, anastomosing chambers about 10.6–45 x 24–120μ, elongated radially; subgleba none.

Spores minute, pale, subspherical or somewhat irregular and minutely warted, 2.5–3.2μ or if elongated up to 3.7μ long. Basidia more than 4-spored, apparently about 5–7-spored, about 3.6–4μ thick, clavate.

Honduras. Lancetilla Valley. P. C. Standley, coll. Path. and Myc. Colls. No. 54842, and U. N. C. Herb).

Allomyces arbuscula

In our notes on *Allomyces arbuscula* (Saprolegniaceae, p. 182) we said we had not found the pores in the cross wall of this plant that had been previously described and figured by Barrett (Bot. Gaz. **54**: 353. 1912). Two or three years ago we gave one of our students (Mr. Adrian Couch) the problem of confirming this observation of Barrett's. He succeeded in fully demonstrating these peculiar perforated cross walls, which are of a really remarkable configuration. The structure, while somewhat variable, shows rather consistently a beautiful wheel appearance in face view of the cross wall. The solid spokes run out almost regularly from a solid central disk. We think it worth while to publish the accompanying photograph showing a typical example (Pl. 9).

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EXPLANATION OF PLATE 8

Figures by Alma Holland

DITIOLA SHOPEI. FIGS. 1–6

Figs. 1, 2. Thick-walled cells from under surface of plant. × 502.
Fig. 3. Basidium with young spores. × 810.
Fig. 4. Spores. × 810.
Figs. 5, 6. Threads of flesh showing long clamp connection and fusing. × 810.

LYCOGALOPSIS SOLMSII. FIGS. 7–14

Fig. 7. Sketch of section through entire plant showing stratification. × 15.
Fig. 8. Section of bit of peridium, inner side below (internal structure merely indicated). × 278.
Fig. 9. Section of bit of plant showing pores. × 68.
Fig. 10. Anastomosing pores. × 952.
Fig. 11. Bits of hyphae from basal pad of mycelium. × 810.
Fig. 12. Bit of capillitium. × 810.
Fig. 13. Spores. × 1620.
Fig. 14. Basidium with spores. × 952.

PLATE 8

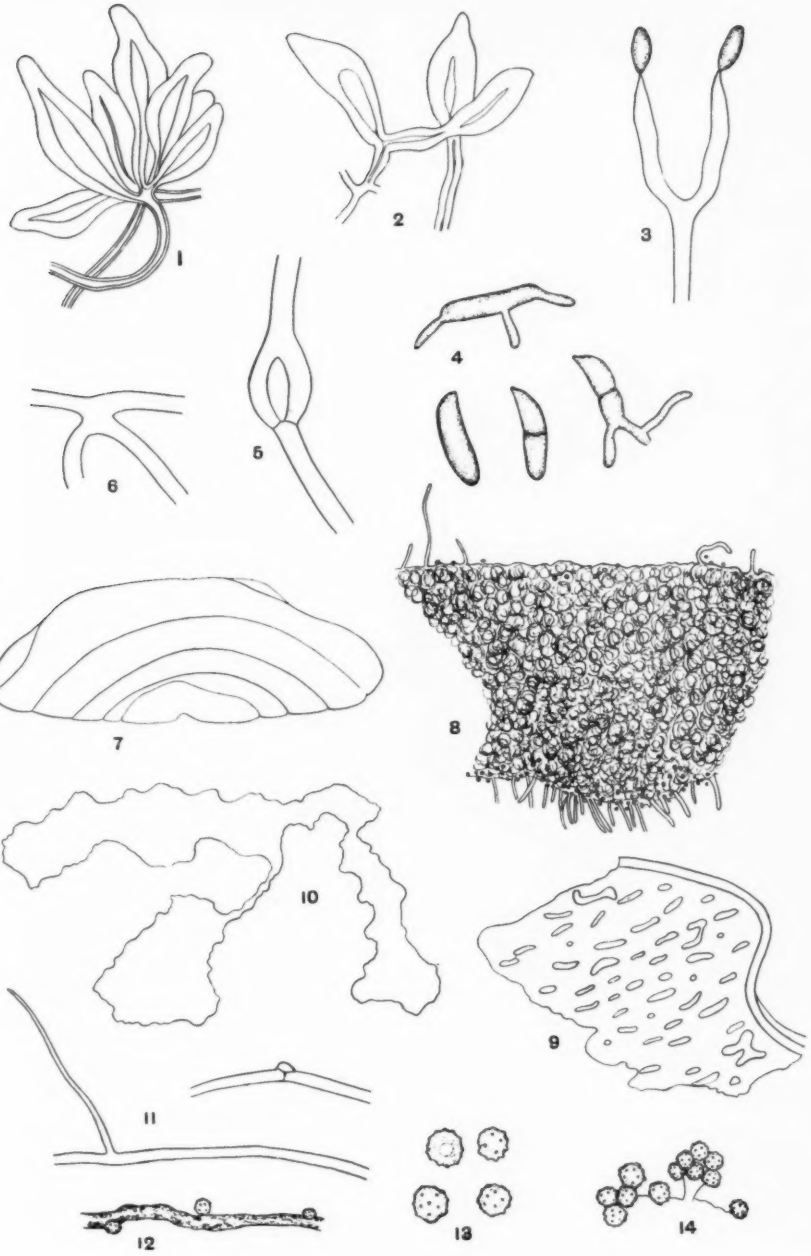

PLATE 9

SHOWING CROSS WALL IN HYPHA OF ALLOMYCES ARBUSCULA
Photograph by Mr. Adrian Couch